Course title: PGE 379/383, The Earth, Natural Resources and Sustainability (19678/19743)

Three hours of lecture per week (TuTh 9:30-11:00 am, CPE2.202)

Instructor: Tad, W. Patzek, Professor, Petroleum & Geosystems Engineering, patzek@mail.utexas.edu

Sponsoring Department: Petroleum & Geosystems Engineering

Cross-listing: ChemE, Civil and Environmental Eng., JSG, ME

Prerequisites: Introductory calculus, physics, chemistry, thermodynamics, and Matlab programming. Most course assignments will be done in Matlab.

Course Grading: 40% Homework, 20% Midterm, 40% Final Exam or Project

Short Course Description

This class deals with the core issues that will determine the future course and survival of humanity. We will apply logic, common sense, the fundamental laws of mass and energy conservation, as well as more advanced thermodynamics to evaluate overall efficiencies of major human energy supply schemes: fossil, nuclear, solar, wind, and biomass. We will define and quantify the irreversible linear processes, and sustainable/unsustainable cycles. The emphasis will be on the relationship between ecosystems (ancient and new), their energy storage and throughput, energy production and its side effects.

Expanded Description

My main goal is to show how the principles of science – physics, thermodynamics, chemistry and biology – apply to the open complex and dynamic living systems. I will also explain how the laws of nature constrain what we may or may not do in terms of energy supply and its environmental impacts.

I will use personal energy consumption and the resulting chemical emissions as a metaphor for human impacts on the Earth. Every student in the class will calculate his/her own carbon emissions and other sources of chemical waste, and decide in what ways he/she could limit these emissions.

The particular subjects covered will be:

1. What the earth can and cannot do for us (Lovelock, 1988; Odum, 1998)?
   (a) Accumulations (coal, petroleum, old growth forest) and fluxes (solar irradiation)
   (b) Differences between old and new solar energy (Odum, 1998) (rate of use, rate of sequestration)
   (c) Ecosystems, their dynamics and equilibria (Odum, 1998)
   (d) The earth as a system closed to mass flow and open to heat flow (Ulanowicz and Hannon, 1987; Patzek, 2004)
   (e) Accumulation of wastes on the earth (Georgescu-Roegen, 1971)
2. Introduction to thermodynamics: Review briefly classical thermodynamics as in (Planck, 1926; Stodola, 1927; Abbott and Van Ness, 1972). Introduce the extended laws of thermodynamics in terms of gradients (Carathéodory, 1976; Hatsopoulos and Keenan, 1965; Kestin, 1966; Schneider and Kay, 1994), but not in terms of classical entropy and free energy.
   (a) Law of mass conservation for an old accumulation and an ecosystem
   (b) First and Second Laws of Thermodynamics for an old accumulation and an ecosystem (Slesser, 1974; Slesser, 1975). Thermodynamic functions in ecosystems (Ulanowicz and Hannon, 1987; Schneider and Kay, 1994; Ho and Ulanowicz, 2005). The Second Law as a manifestation of the arrow of time (Georgescu-Roegen, 1971; Kondepudi and Prigogine, 1998)
   (c) Entropy, free energy, availability (exergy), dissipation of imposed gradients
   (d) Bénard cell, Belousov-Zhabotinskii reaction (Benini et al., 1996), and an unstressed and stressed ecosystem (Schneider and Kay, 1994; May,

2001) as gradient dissipators; self-organization; dissipative structures. What are the special properties of living organisms (Schrödinger, 1996; Schneider and Kay, 1994; Ulanowicz and Hannon, 1987)?

3. Solar spectrum, reflection, transmission and adsorption of solar energy

4. Earth as a thermodynamic machine and a system open to heat flow, but closed to mass flow (Stodola, 1927; Keenan, 1951)

5. Photosynthesis and its energy efficiency (Good and Bell, 1980; Taiz and Zeiger, 1998; Odum, 1998) (the Hill reaction, theoretical photosynthetic efficiency, practical efficiency as deduced from the CO_2 fluxes with eddy-covariance method)

6. Energy efficiencies of major crop systems (Patzek, 2004; Patzek and Pimentel, 2005)

7. Solar cells and their overall energy efficiency

8. Wind turbines and their overall energy efficiency

9. Carbon, nitrogen and sulfur cycles (Smil, 1985)

10. Mineral and micro-element cycles as in (Patzek, 2004; Patzek and Pimentel, 2005; Reich et al., 2006)

11. Thermodynamic requirements for ecosystem survival and stability (sustainability) as in (Ulanowicz and Hannon, 1987; Schneider and Kay, 1994; Ho and Ulanowicz, 2005; Patzek, 2004; Patzek and Pimentel, 2005)

12. Multiscale storage of energy in natural ecosystems vs. simplified, man-made ecosystems (Schneider and Kay, 1994; Ulanowicz and Hannon, 1987; Ho and Ulanowicz, 2005)

13. Net biomass productivity (Patzek, 2004; Patzek and Pimentel, 2005; Kimbrell, 2002; Cavalli-Sforza and Cavalli-Sforza, 1995)

14. Biofuel production schemes: fermentation, pelleting, and gasification (Patzek, 2004; Patzek and Pimentel, 2005)

15. Old plant energy: coal

16. Old plant energy: petroleum, and natural gas

17. Thermodynamics of petroleum recovery schemes

18. Nuclear energy

19. How does it all fit together?

References

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