Sustainable Development:  
Ethics, Physics and Technology

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Course Description
Although sustainability and sustainable development have become common themes in public discourse there is little consensus on how to translate these concepts into decisions and actions in the realms of policy, technology, economics, environment. This course will examine the focal issue underlying sustainable development, change and its limits, from different perspectives: ethics, dynamics, physics, technology. Selected applications in various disciplines and economic sectors will be discussed. The course will introduce several mathematical and physical concepts in a rigorous way but with emphasis on understanding these concepts rather than on technical details. Basic college physics and calculus classes would be beneficial for the student. In line with the “learning by doing” philosophy, students are expected to participate in the class in an active way through discussions, assignments and readings.

Course Requirements (details to be announced in the first meeting)
- one term project (preferably as a 2-3 person team) with a written report;
- one extended classroom presentation
- participation in class discussions (oral and written)

Course website
The course will have a website to manage resources (articles, responses, discussions). The site is hosted by UCBerkeley system. You need to send me an e-mail and I register you as a participant.
Course Outline

Meetings 1-2
Concept of sustainability and sustainable development
The course will start examining the basic question: what to sustain and what to develop? This question will be discussed initially from the philosophical and moral perspective addressing the following issues:
- How to reconcile changes in natural and social environment with expectations and desires of stability and predictability?
- Revolution and creative disruption versus evolution
- Aspects of sustainability and development: social, economic and environmental
- Physical sustainability: living within the laws of nature
- Intragenerational and intergenerational equity: validity and applicability of long-term discount rates
- Example of a specific “sustainability case”

Readings:


Meeting 3
Sustainability and Water Resources

Readings:

**Meeting 4**

**Change and Dynamics**
This part of the course will be devoted to examination of system dynamics with a goal to develop an understanding of generic patterns of change such as cycles, equilibria and chaotic behavior. These ideas and related dynamic characteristics will be applied to real ecological systems to recognize their dynamic properties in the phase-space such as stability, periodicity, characteristic times, etc. Specifically, some of the following topics will be addressed:
- System description: intrinsic and extrinsic properties, state variables, degrees of freedom
- Phase space and representation of system dynamics as trajectories in phase space
- Generic dynamic behavior: equilibrium (fixed points), cycles (limit cycles), quasiperiodicity, strange attractors
- Reconstruction of system dynamics from observables: Fourier analysis, Taken’s theorem, applications to real-world problems: Earth climate, California water system, Aral Sea
- Characterization of dynamics: dissipative and conservative systems, Lyapunov exponents
- Entropy: system-theoretical approach and connection to limit behaviors of dynamical systems

**Meetings 5-6**

**Energy, Entropy and Materials: Global and Local Views**
The third part of the course will attempt to examine sustainability through the lens of well-established physical properties: energy and entropy. This approach is based on the first and second laws of thermodynamics that can provide a scientific and quantitative basis for the discussion of technical, social and policy options. Use and cycling of natural resources will be also addressed. The topics will include:
- Earth as a closed-mass energy-driven system
- Sources of energy: renewables, non-renewables, dynamics of energy transformations
- Quality of energy: exergy
- Sources of high-quality energy (high exergy): oil, coal, natural gas, nuclear, solar, hydro, bio
- Energy and exergy balance: historical perspective, current picture and possible future.
- Material resources: availability and balances
- Energy input and economic output
- Entropy as a measure of system or process performance, reversibility of entropy increases
- Entropy: thermodynamic, system-theoretic, and information-theoretic approaches
- Entropy in economics: Nicholas Georgescu-Roegen, Herman Daly, Robert Costanza and ecological economics
- Applications of energy and entropy to characterize physical sustainability: examples in water treatment, resource recovery and recycling
Meetings 6 - 8

Real World Applications
The last section of the course will deal with selected attempts to apply the concepts of sustainability in the real world. Actual selection of case studies and example will depend on student interests. This section will provide students with opportunities to present results of their term projects to the class. Some possibilities are listed as follows:
- Green buildings: LEED
- Efficient lightning
- Sustainable agriculture and forestry
- Ecological footprint: concept and critique
- Ecological rucksack: dematerialization
- Factor 10
- Ethanol as fuel
- Life Cycle Assessment
- Water resources management, water reclamation and reuse, desalination
- Nutrient recovery from wastewater
- Sustainable transportation
- other topics depending on the students’ interests

Possible Starting Sources:
US Green Building Council www.usgbc.org
World Business Council on Sustainable Development www.wbcsd.org
Institute of Environmental Sciences www.leidenuniv.nl/interfac/cml/index.html
The Economist www.economist.com
US EPA Life-Cycle Assessment Research www.epa.gov/ORD/NRMRL/lcaccess/resources.html
The Wuppertal Institute www.wupperinst.org
Rocky Mountain Institute www.rmi.org
Factor 10 Institute www.factor10-institute.org and Faktor 10 Institut (Austria) www.faktor10.at