# Sustainable Development:
# Ethics, Physics and Technology

***Proposed Course Syllabus***

**University of Natural Resources and Applied Life Sciences - BOKU, Vienna**

Award #8007

**Slav W. Hermanowicz**, Ph.D.
Department of Civil and Environmental Engineering
University of California, Berkeley, CA 94720, USA

## 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 Format

One semester; lectures and seminars to conform with the host institution standards for 3 ECTS points which is a "normal" course value at BOKU. The teaching/learning cycle will consist of formal lectures, organized discussions and projects (assigned and student-chosen).

## Course Requirements

- three term projects (preferably as a 2-3 person team) with written reports
- one extended classroom presentation
- preparing and leading at least one session of discussion

The requirements will be modified depending on the number of students and host institution requirements.

## Course Outline

***Weeks 1 - 3***

**1. 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

Representative readings:

Ayres, R.U., van den Bergh, J.,Gowdy, J.M. (2001). Strong versus weak sustainability: Economics, natural sciences, and "consilience". *Environmental Ethics* 23(2), 155-168

Allenby, B.R. (2000). Environmental security: Concept and implementation. *International Political Science Review* 21(1), 5-21

Beckerman, W. (2003). A poverty of reason : sustainable development and economic growth. Oakland, Calif., Independent Institute.

Clark, W.C.,Dickson, N.M. (2003). Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences of the United States of America* 100(14), 8059-8061

Costanza, R. (2003). Social goals and the valuation of natural capital. *Environmental Monitoring and Assessment* 86(1-2), 19-28

Costanza, R., dArge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., Oneill, R.V., Paruelo, J., Raskin, R.G., Sutton, P.,vandenBelt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature* 387(6630), 253-260

Graedel, T.E.,Klee, R.J. (2002). Getting serious about sustainability. *Environmental Science & Technology* 36(4), 523-529

Hermanowicz, S.W. (2006). "Sustainable Development: Physical and Moral Issues". Water Resources Center Archives. Working Paper swr_1206. http://repositories.cdlib.org/wrca/wp/swr_1206

Holliday, C.O., Schmidheiny, S., Watts, P. (2002). Walking the talk : the business case for sustainable development. Sheffield, Greenleaf.

Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grubler, A., Huntley, B., Jager, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H., Moore, B., O'Riordan, T.,Svedin, U. (2001). Environment and development - Sustainability science. *Science* 292(5517), 641-642

Kates, R.W.,Parris, T.M. (2003). Long-term trends and a sustainability transition. *Proceedings of the National Academy of Sciences of the United States of America* 100(14), 8062-8067
Parris, T.M.,Kates, R.W. (2003). Characterizing and measuring sustainable development. *Annual Review of Environment and Resources* 28 559-586
Nordhaus, W. (2007). Critical assumptions in the Stern review on climate change. *Science* 317(5835), 201-202
Stern, N.,Taylor, C. (2007). Climate change: Risk, ethics, and the Stern Review. *Science* 317(5835), 203-204 and documents on www.sternreview.org.uk
World Commission on Environment and Development (1987). Our common future. Oxford ; New York, Oxford University Press.

***Weeks 4 - 5***

**2. Change and Dynamics** *(partially based on my previous course "Chaos, Fractals and Complexity")*

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, 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

Representative readings:

Addison, P.S. (1997). Fractals and chaos : an illustrated course. Bristol, UK ; Philadelphia, Institute of Physics Pub.
Cabezas, H., Pawowski, C.W., Mayer, A.L.,Hoagland, N.T. (2005). Sustainable systems theory: ecological and other aspects. *Journal of Cleaner Production* 13(5), 455-467
Costanza, R., Wainger, L., Folke, C.,Maler, K.G. (1993). Modeling Complex Ecological Economic-Systems - toward an Evolutionary, Dynamic Understanding of People and Nature. *Bioscience* 43(8), 545-555
Daly, H.E. (1992). Is the Entropy Law Relevant to the Economics of Natural-Resource Scarcity - Yes, of Course It Is. *Journal of Environmental Economics and Management* 23(1), 91-95
Davies, B. (1999). Exploring chaos : theory and experiment. Reading, Mass., Perseus Books.
Hjorth, P.,Bagheri, A. (2006). Navigating towards sustainable development: A system dynamics approach. *Futures* 38(1), 74-92

Holmberg, J., Lundqvist, U., Robert, K.H.,Wackernagel, M. (1999). The ecological footprint from a systems perspective of sustainability. *International Journal of Sustainable Development and World Ecology* 6(1), 17-33

Limburg, K.E., O'Neill, R.V., Costanza, R.,Farber, S. (2002). Complex systems and valuation. *Ecological Economics* 41(3), 409-420

Pawlowski, C.W., Fath, B.D., Mayer, A.L.,Cabezas, H. (2005). Towards a sustainability index using information theory. *Energy* 30(8), 1221-1231

Rechberger, H.,Brunner, P.H. (2002). A new, entropy based method to support waste and resource management decisions. *Environmental Science & Technology* 36(4), 809-816

***Weeks 6 - 10***

**3. 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

<u>Representative readings:</u>

Ahlbrandt, T.S. (2002). Future petroleum energy resources of the world. *International Geology Review* 44(12), 1092-1104

Ayres, R.U. (1997). Metals recycling: economic and environmental implications. *Resources Conservation and Recycling* 21(3), 145-173

Ayres, R.U., Ayres, L.W.,Martinas, K. (1998). Exergy, waste accounting, and life-cycle analysis. *Energy* 23(5), 355-363

Cleveland, C.J.,Ruth, M. (1997). When, where, and by how much do biophysical limits constrain the economic process? A survey of Nicholas Georgescu-Roegen's contribution to ecological

economics. *Ecological Economics* 22(3), 203-223
Desrochers, P. (2000). Market Processes and the Closing of "Industrial Loops": A Historical Reappraisal. *Journal of Industrial Ecology* 4(1), 29-43
Farrell, A.E., Plevin, R.J., Turner, B.T., Jones, A.D., O'Hare, M.,Kammen, D.M. (2006). Ethanol Can Contribute to Energy and Environmental Goals. *Science* 311(5760), 506-508
Graedel, T.E., Bertram, M., Fuse, K., Gordon, R.B., Lifset, R., Rechberger, H.,Spatari, S. (2002). The contemporary European copper cycle: The characterization of technological copper cycles. *Ecological Economics* 42(1-2), 9-26
Haberl, H., Wackernagel, M.,Wrbka, T. (2004). Land use and sustainability indicators. An introduction. *Land Use Policy* 21(3), 193-198
Hoffert, M.I., Caldeira, K., Benford, G., Criswell, D.R., Green, C., Herzog, H., Jain, A.K., Kheshgi, H.S., Lackner, K.S., Lewis, J.S., Lightfoot, H.D., Manheimer, W., Mankins, J.C., Mauel, M.E., Perkins, L.J., Schlesinger, M.E., Volk, T.,Wigley, T.M.L. (2002). Advanced technology paths to global climate stability: Energy for a greenhouse planet. *Science* 298(5595), 981-987
Hubbert, M.K. (1981). The Worlds Evolving Energy System. *American Journal of Physics* 49(11), 1007-1029
Huesemann, M.H. (2003). Recognizing the limits of environmental science and technology. *Environmental Science & Technology* 37(13), 259A-261A
Koonin, S.E. (2006). Getting serious about biofuels. *Science* 311(5760), 435-435 and following discussions
Landon, S.M. (2002). Energy: Yesterday, today, and the opportunities and challenges of tomorrow. *International Geology Review* 44(12), 1105-1114
Ragauskas, A.J., Williams, C.K., Davison, B.H., Britovsek, G., Cairney, J., Eckert, C.A., Frederick, W.J., Jr., Hallett, J.P., Leak, D.J., Liotta, C.L., Mielenz, J.R., Murphy, R., Templer, R.,Tschaplinski, T. (2006). The Path Forward for Biofuels and Biomaterials. *Science* 311(5760), 484-489
Wackernagel, M., Monfreda, C., Erb, K.H., Haberl, H.,Schulz, N.B. (2004). Ecological footprint time series of Austria, the Philippines, and South Korea for 1961-1999: comparing the conventional approach to an 'actual land area' approach. *Land Use Policy* 21(3), 261-269

***Weeks 11 - 15***

**4. 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