Sustainable Engineering Principles: CL665

Instructor:

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Course outline:

Achieving sustainable development by balancing the long-term economic, environmental and societal objectives is one of the most complex scientific problems of our times. Engineering designs need to increasingly incorporate these aspects in decision making. However, translating the concepts of sustainability into decision making is not trivial. This topic goes beyond the traditional areas of process development, process design, and industrial ecology, and encompasses multi-scale phenomena and complex interactions of multiple disciplines. It becomes essential to take a holistic view and develop systems based solutions. It is also important to expose students to the various methods and tools that can be used for designing sustainable systems. These methods and tools are based on fundamental concepts in engineering such as mass and energy balance, thermodynamics, and probability and statistics. This course will aim to achieve this objective. The course is intended to teach students the fundamentals of sustainability as well as quantitative methods and tools that can be used for decision making (design) for sustainability.

Course Content (subject to revision):

Part I: Overview and basics (~4 hours)

- Basics of sustainability and sustainable development
- Brundtland commission report, Millennium Ecosystems Assessment, IPCC report
- Evolution from green engineering to sustainable engineering
- Motivating examples from chemical as well as other branches of engineering

Part II: Sustainability quantification (~15 hours)

- Why quantification is important?
- Different quantification methods:
  - Brief review of well established economic indicators
  - Footprint analysis (carbon footprint, water footprint)
  - Life cycle inventory and assessment
  - Ecological/environmental carrying capacity
  - Information theory based indicators for dynamic systems
  - Resource use intensity
  - Exergy, emergy etc.
  - Social indicators

Part III: Design of sustainable systems (~15 hours)

- Importance of incorporating sustainability in design
- Examples of sustainable designs
- Design methods for sustainability
  - Moving from quantification to decision making (design)
  - LCA
  - System dynamics models
  - Other methods
- 1-2 Hands-on activities using freely available tools such as the OpenLCA (http://www.openlca.org/)

Part IV: Case studies: Sustainable design in chemical engineering and other allied fields (~ 6 hours)

- Examples of performing sustainable design from different fields such as a energy, water, material use, solvent selection, ionic liquids
- Guest lectures by domain experts, and demonstration using educational modules (e.g. Center for Sustainable Engineering, http://www.csengin.org/csengine/)

Texts/References:

The course will be quite interdisciplinary and there is no standard textbook that is recommended for the course. Material from several books, technical reports by national and international agencies, and research/review articles will be used. The important sources to be used are:

- Heriberto Cabezas, Urmila Diwekar (Editors). Sustainability: Multi-Disciplinary Perspectives. Bentham Science, 2012, ISBN 978-1-60805-429-9
- Bhavik R. Bakshi, Timothy G. Gutowski, Dusan P. Sekulic (Editors) .Thermodynamics and the Destruction of Resources, 2011, ISBN-13: 978-0521884556
- David Allen, David Shonnard. Green Engineering: Environmentally Conscious Design of Chemical Processes. Prentice Hall PTR, New Jersey, USA, 2001 ISBN-13: 978-0130619082
- Martin A.A. Abraham. Sustainability Science and Engineering, Volume 1: Defining Principles. Elsevier Science, 2007, ISBN-13: 978-0444517128
- C. Tomlinson. Our Common Future. World Commission on Environment and Development, Oxford University Press, Oxford, 1987.
- Millennium Ecosystem Assessment. Ecosystems and human well-being: Scenarios (global and multi-scale assessment reports). Technical report, Millennium Ecosystem Assessment, 2005.
- IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T.F. Stocker, D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. Midgley (Eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.