Integration of Semiconductor Manufacturing Concerns in a Green Design Course

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Green design is **not** abatement!

Green design is the rational implementation of conscious choices that minimize environmental impacts while meeting economic constraints.

ChEE 455/555 - Environmentally Benign Design of Chemical Processes

A senior/graduate student elective course

3 credits

Course Description:

This course will introduce you to the fundamental principles surrounding environmentally benign design of chemical processes. It will expose you to the social, economic, environmental and physical principles that must be balanced to create sustainable processes for manufacturing chemicals and products. Specifically, students will use **green chemistry** approached combined with **life cycle assessment** techniques to evaluate, improve, and re**design chemical engineering processes**.

Some Course Details

Prerequisites:
Undergraduate students should have completed ChEE 442
Graduate students should be in the chemical, environmental, biomedical, or mechanical engineering graduate programs

Text: Green Chemistry: Theory and Practice by P. T. Anastas and J. C. Warner, Oxford University Press, New York (1998).
Additional materials will be available as a coursepack online at
http://www.che.arizona.edu/Directory/Faculty/Blowers.htm

Current Students

Graduate	Undergraduate
Lateef Mustafa	Eric Weisman
Jennifer Wilcox	Stephanie Carroll
Xiaobo Zheng	Beverly Toperzer
Tao Zhu	Jessica Smid
Nianliu Zheng	Brad Sohm
	Laura Kinn
	Brent Page

Course Objectives

1) Be able to discuss the implications of green design in the context of environmental and economic costs.

2) Be able to implement life cycle assessment on individual chemical engineering process flowsheets.

3) Be able to discuss the limitations, strengths, and uses of life cycle assessment methods applied to chemical engineering problems.

4) Be able to evaluate current chemical processes to identify environmental and economic impacts.

5) Be able to identify methods for improving the environmental and economic performances of chemical processes.

Course Objectives Continued

6) Be able to explain to other engineers the reasoning behind green chemistry and life cycle assessment methodologies.

7) Be able to read and critique published life cycle assessments for their individual strengths and weaknesses.

8) Be able to search for and use highly specific information in the published literature and to evaluate the relevance of the materials. Be able to effectively use library resources

Other Metaobjectives

1) Be able to communicate effectively in short written reports

2) Be able to present material orally to peers

3) Be able to perform literature searches for specific information that is needed

4) Be able to work effectively in teams to achieve multi-goal objectives

Graduate Student Requirements

Do a literature search on a specific LCA topic of your choice.

Find at least 10 references on your topic, but your final product from this project will include only the five that you favor as being the best.

Give a short presentation of your topic that is 30 minutes long.

Discuss why you selected your topic involving LCA, how you found references to investigate your topic, and a brief explanation of the content of the five papers you use to explain your topic

Summary of Evaluation Criteria for Graduate Student Projects:

1) clarity of presentation

2) quality of ideas presented

3) ability to rationalize choice of references and why some references were not chosen

4) ability to describe the many routes of gathering information you used to get to each paper

Average Scores from Student Pre-Evaluation

environmental impacts of chemical processes	4.833333
economic costs of chemical processes	5.083333
application of LCA to chemical processes	2.666667
Limitations of LCA	2.583333
Strengths of LCA	2.666667
ability to read technical papers	5.333333
ability to communicate orally	6.5
ability to function in teams	7.666667
ability to use the library resources to find information	6.666667
be able to judge the accuracy of published articles	4.416667
be able to write short communications	6.5

Topics Covered

Life Cycle Assessment Techniques (LCA) and their limitations

Green Chemistry and problems with implementing it

Environmental economics and regulations

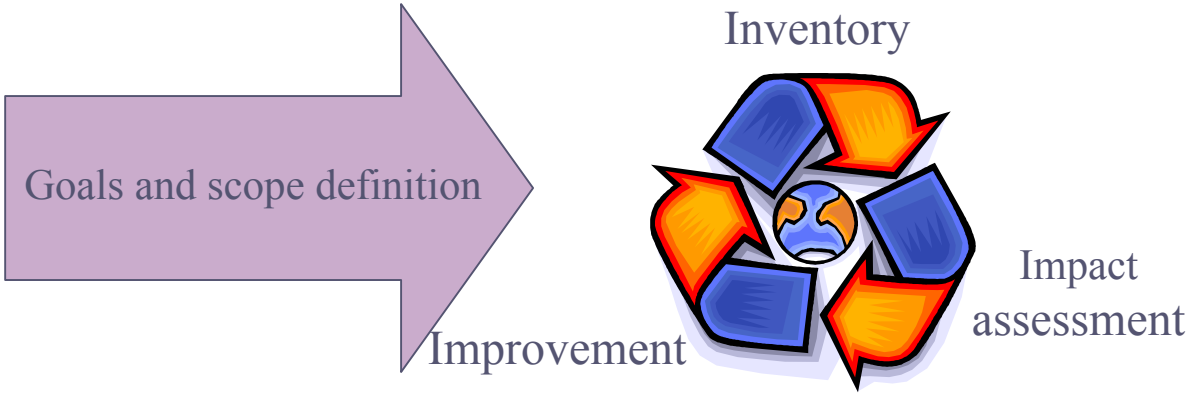
Integration of all Topics into a Working Framework

What is LCA and its Uses?

LCA is an analytic tool for quantifying the environmental impacts of all processes used in converting raw materials into a final product. It consists of three parts, life cycle inventory, impact assessment, and life cycle improvement.

Life cycle studies have been used to understand three types of problem:

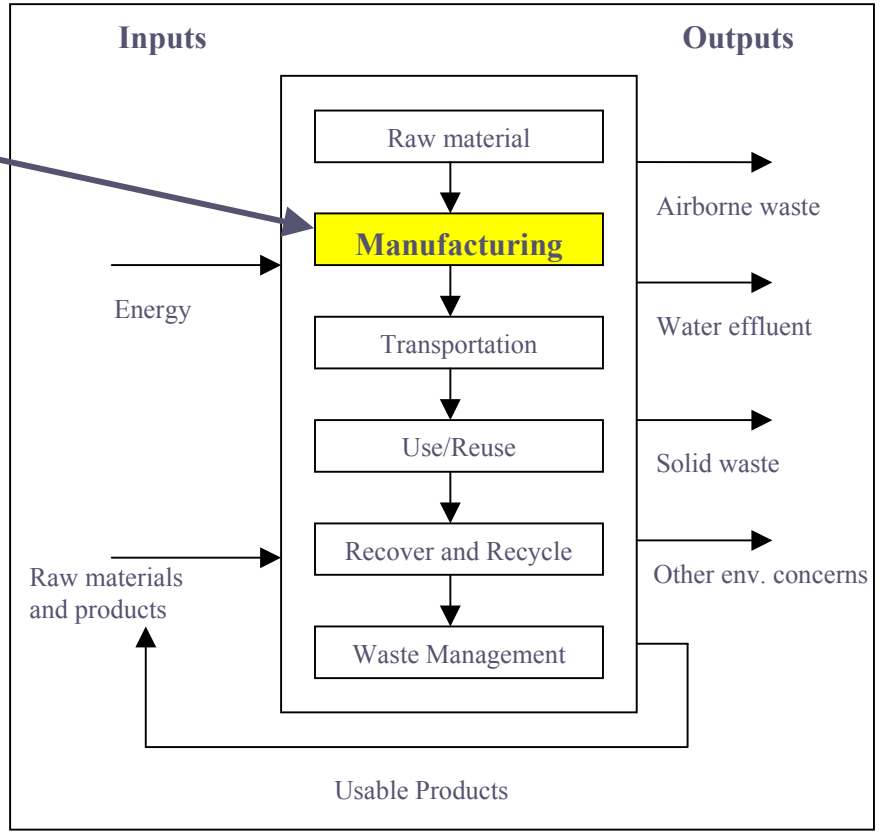
- Assessments of single products to learn about their eco-profiles.
- Comparisons of process routes in the production of substitutable products of processes.
- Comparisons of alternative ways for delivering a given service or function.



Externalities and LCA

Concerns from industry primarily on semiconductor manufacturing. Do not look at "bigger LCA picture".

This project will also address other ESH concerns that result from our processing choices.



Full Life Cycle Assessment

LCA would investigate upstream fluorine-species generation as an impact.

Excerpt from a Sample HW Assignment

For this homework assignment, list all of the considerations that you can think of that we should take into account when we are rating the hazards of chemicals that appear within our process and the process itself. What impacts of a chemical should be included in our environmental assessment? What process considerations may be important when designing our process?

Summary of Evaluation Criteria:

1) number of ideas generated

2) quality of ideas generated

3) participation in class discussion

Another HW with Different Objectives

For this homework, read the series of papers that begins with "Life-Cycle Analysis of Alternative Automobile Fuel/Propulsion Technologies". Read the two comments on this paper that appeared in subsequent issues of the journal. Discuss your opinion on the series of papers. Based on common sense and other things that you know from your technical background, how would you respond to this article? You must support your position with at least three other articles from the library and cite them properly. Your final position paper should be no more than two pages double spaced.

Summary of Evaluation Criteria:

1) correct language usage
2) correct format
3) cited references
4) well formulated opinion and response

Meta and Normal Objectives within One Assignment

We've now read the paper by Carmo J. Periera called Environmentally Friendly Processes. Figure 3 showed how a typical process goes through a life cycle. Note that this type of life cycle is similar to the life cycle of a product, but deals instead with the chemical plant itself. Find a reference that discusses some of the issues of this type of life cycle including the decommissioning phase of a chemical plant. Summarize your findings so you can make a short presentation in class about the facility and the long-term effects of decommissioning the chemical plant.

Summary of Evaluation Criteria:

1) ability to summarize a paper concisely

2) ability to communicate the summary

Course Projects

1) Closed-Ended LCA of part of a process for fossil fuel or bio-diesel

set boundaries, gather data, evaluate process

2) Open Ended evaluation of current manufacturing practices in

semiconductor manufacturing involving engineering estimation

Done in small groups to strengthen communication skills

Culminates in 20 minute long summary presentation of materials

Elements of a Successful Project:

A concise presentation with clear structure

A list of boundaries drawn for the investigation

A list of assumptions made

A summary of environmental impacts of the process

A rough estimate of process economics

A brief discussion of of tradeoffs to be made when changing the process

A preliminary list of impacts external to the flowsheet and where you would focus further information gathering efforts

Student Comments about the First Project

"It was difficult finding specific information that we could verify"

"It was difficult giving a concise oral report on such a complex topic"

"If I did it again, I'd start questioning assumptions earlier"

All in all, students seemed pleased with their progress in learning during the project, particularly in delegation skills

Current State of Educational Materials

There is only one book that discusses Green Design within chemical engineering and it was published last November. It doesn't concentrate as fully on evaluation as may be useful.

Other texts are slow in coming…but publishers are extremely interested in getting more out.

Very few project based materials to teach these topics are available, particularly none in chemical engineering.

External Support for Development of Materials

Current:

The Dreyfus Foundation - 2 year development and dissemination of project based materials

Pending:

The Lindbergh Foundation - 1 year development of integrated materials for green design in chemical engineering.

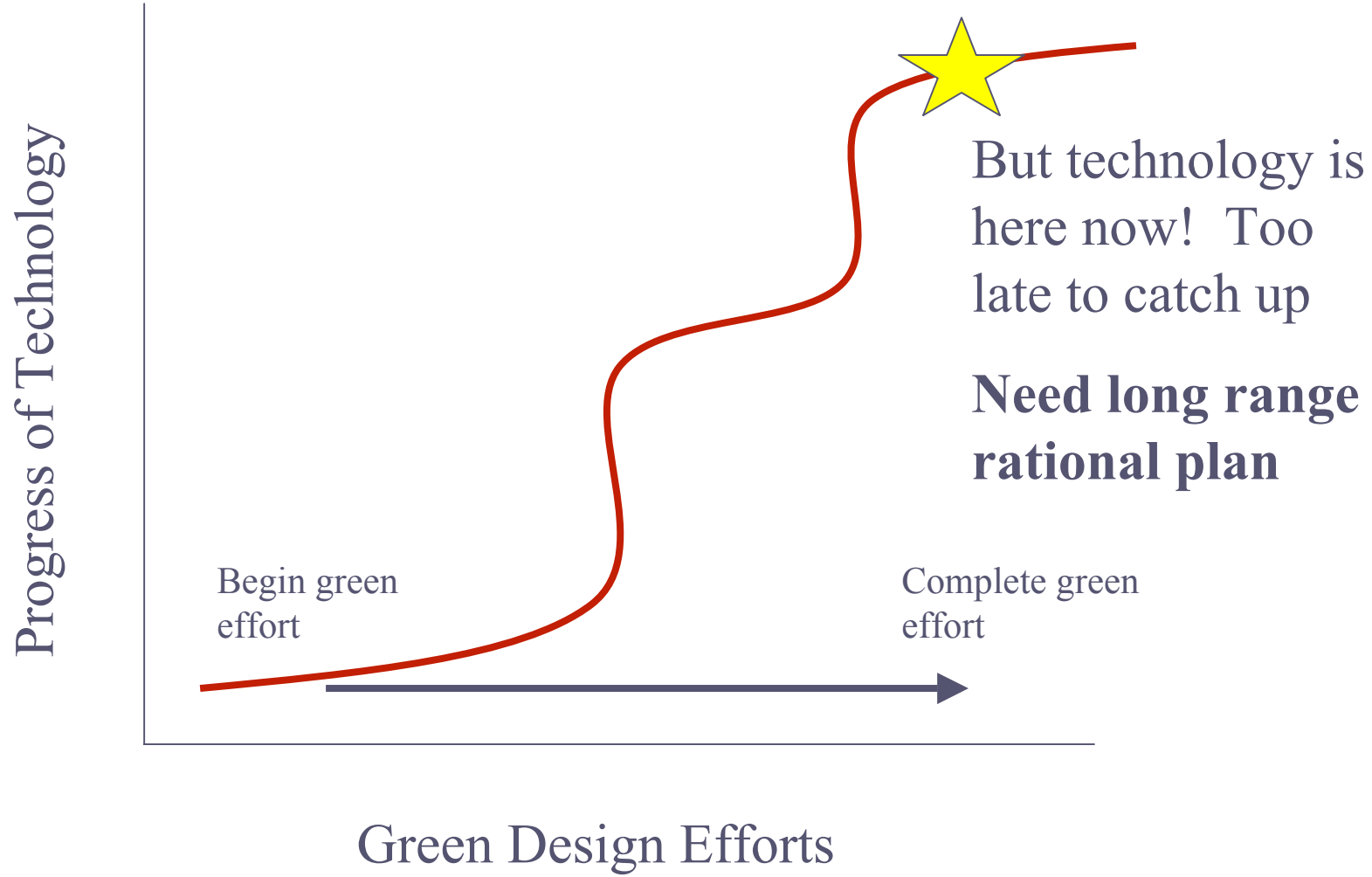
The Difficulties of Implementing Green Design in the Semiconductor Industry

Competition is high among companies as better technologies are developed

Technologies change very rapidly so it is difficult to approach green design in traditional ways

In contrast, stable industries with long histories and less competition or new industries with no history find it easier to implement green design

Hitting a Moving Target is Difficult!



What would be Most Useful to the Semiconductor Industry to Include in the Green Design Course?

(Open Discussion)

Please offer ideas on concepts and skills that would be immediately useful for students to possess upon graduation and employment in the semiconductor industry.

Acknowledgments

The ERC for supporting a graduate seed project to evaluate fluorine compounds in semiconductor manufacturing

The Dreyfus foundation for supporting development of project materials