ENGS 37
INTRODUCTION to
ENVIRONMENTAL ENGINEERING
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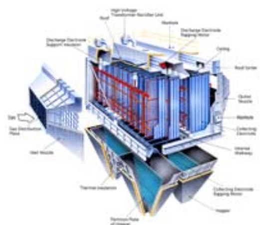


We live in incredibly rich and prosperous times.

Never before has the typical human possessed the ability to control or manipulate as many resources as today.

Think about this:

Today, one individual can manipulate an incredible amount of resources thanks to technology!

Everything is soon to be trash…

Nice running car

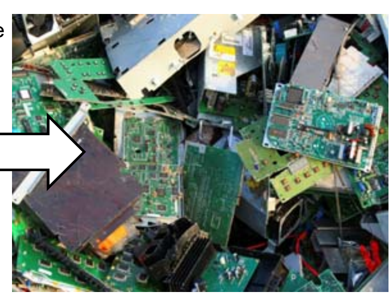
Time

Rusty hulk

Laptop

Time

e-Waste



… and we return more wastes to our environment than ever before.

Treatment of effluents is necessary.
Clean-up after an accident must be done.
Clean technologies should be designed.
Limits must be discerned.

That's where
Environmental Engineering
comes in.

What is Environmental Engineering?

The discipline is largely defined by problems rather than by technical/scientific methods.

Typical problems:

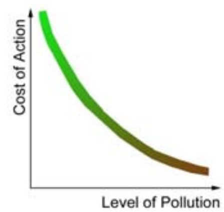
Remediation of a contaminated site (= fixing the past),
Treatment of a dirty effluent (= dealing with the present),
Pollution avoidance (= planning for the future).

Breadth, interdisciplinarity:

Systems thinking, various engineering disciplines, even non-engineering disciplines.

Challenges:

Avoidance of moving one waste from one phase to another
(*ex*. air to water or water to solid waste)
Prevention is harder than treatment
Environmental benefit versus economic burden (trade-off).



Role of the public sector:

In other areas of engineering, a ***need*** creates a market, and the market drives technology development. In environmental engineering, it starts with a ***problem***, which drives regulations, regulations create the market, and the market drives the technology.

Structure of the course

Context & Motivation
- the Sustainability imperative
- the role of engineers in sustainability

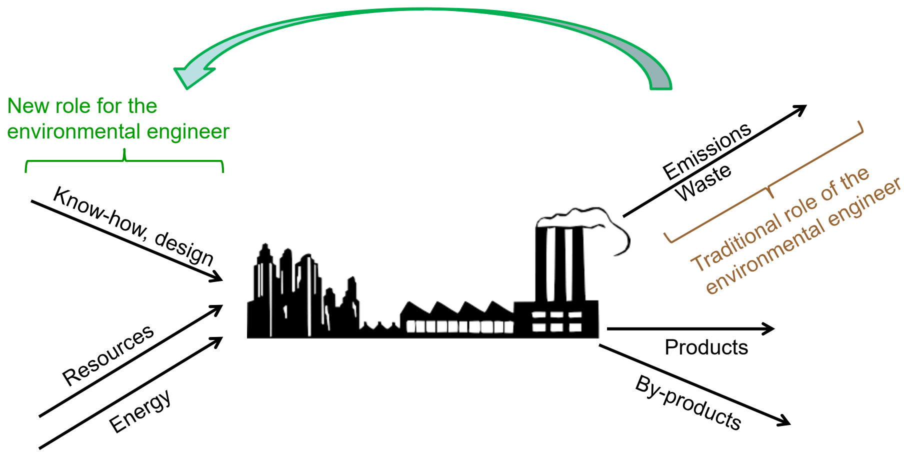
Preliminaries
- Relevant quantities (concentrations, fluxes)
- Material balances
- Transport processes
- Environmental chemistry

Forms of Pollution & Treatment Technologies
- Water pollution → water-treatment technologies
- Air pollution → air-quality technologies

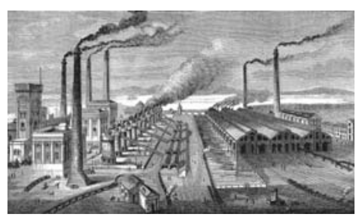
Resource management → Risk assessment, Sustainability

Prevention methods → "Sustainable Engineering"
- Design for Environment
- Industrial Ecology
- Energy conservation
- Renewable forms of energy
- Addressing climate change

Business as usual won't do. It is unsustainable, both in terms of
– procurement of new resources (upstream end)
– environmental capacity to absorb our consequences (downstream end).



Consider this:



- Engineers are responsible for the Industrial Revolution.
- The Industrial Revolution has spread across the globe.
- There is a growing set of negative consequences, some local and some global.

Thus, it stands to reason that engineers are called to play a central role in
- amending current technological practices, and
- designing and deploying sustainable technologies.

Note: This does not require a return to the distant past.
A healthy (functional) planet is not necessarily a pristine (untouched) planet.

A historical example of healthy versus pristine

Back in the days when England and France were rivals in Europe, the English used their powerful navy to land in France and occupy entire regions like Burgundy, causing endless wars, one of which got called the *Hundred Years' War* (137-1453).

Tired of this, the French monarch decided that the French had to vanquish the English and the only sure way to do this was to beat them at their strength. That meant to beat their royal navy at sea. So, the French King decided to build a navy that would rival the English one.

Back then, warships were made of timber, and building an entire fleet required cutting down entire forests. And, so it was that France got deforested in a major way.

All that land was later turned into pasture and croplands, and food became plentiful.

To this day, France is a food exporting country.
No one seems to miss the old forests.

Surely, species (ex. wolves) disappeared, but others (ex. hawks) took their place in a new ecological system. The climate, too, must have been altered to some degree, but the territory is eminently very livable.

Historical and geographical perspective

The historical roots of environmental engineering are for the most part associated with effluent treatment and civil engineering. Indeed, environmental engineering began with "sanitary engineering" (= sewage treatment), and to this date "Civil and Environmental Engineering" departments are common in academia.

http://www.sewerhistory.org/images/w/web/egouts-681.jpg

In general, awareness of water pollution preceded awareness of air pollution, which itself preceded awareness of solid wastes, especially hazardous wastes; and the relative maturity of treatment technology is
water > air > solid waste > hazardous material.

In the *developed world*, effluent treatment technologies are widely applied and make possible the population density and intensity of resource use that exist today. Further application of effluent-treatment technologies in the industrialized countries offers diminishing returns, and pollution problems associated with non-point sources (*ex*. agriculture, transportation), scarcity of land for landfills, and resource availability assume increasing importance. The challenges are technical and demand a change of paradigm away from excessive consumption.

In the *developing world*, the widespread lack of adequate effluent-treatment technology is commonly the primary immediate technologically-accessible challenge impeding improved environmental quality. The barriers to meeting this challenge are usually not technical, but involve financial, institutional, infrastructure and, in some cases, cultural considerations.

Environmental remediation

http://www.lenoci.hu/projects.htm

= fixing the past by cleaning up contaminated areas after wastes have been released into the environment.

Environmental remediation typically focuses on toxic and hazardous substances and involves far higher costs than those associated with effluent treatment prior to discharge. There are also legal expenses associated with litigation, often concerning responsibility.

Environmental remediation involves chemical reaction, physical separation, or a combination of these, and may be carried out either by removing contaminated material for treatment/disposal at a separate location or in some cases may be accomplished in place ("*in situ*") without such removal.

Treatment and transportation of hazardous materials is a highly regulated activity in the U.S. and many other countries.

Effluent Treatment

Handling wastes at present by designing devices that treat effluents that would otherwise pollute the environment

http://www.hanovernh.org/pages/HanoverNH_PublicWorks/WaterRecl/index

http://www.indiamart.com/enhanceenvirotech/

Technologies involve reaction, separation, or a combination of these, and may be considered for pollutants arising in all phases of matter: gaseous, liquid, and solid.

Frequently, a given effluent treatment technology can be applied to wastes arising from a wide diversity of processes. Thus for example, the design principles for an activated sludge treatment system are largely the same whether the system is treating domestic sewage or wastewater after manufacture of chemicals, paper, or food products. Likewise, electrostatic precipitators can remove particles from dusty airflows in a variety of technological processes.

Distinction needs to be made between so-called *point sources* (such as a power plant) and *distributed sources* (such as traffic and agricultural runoff). Treatment of effluent from distributed sources is far more complicated than that from point sources.

Design for environment

Design for the Environment U.S. EPA

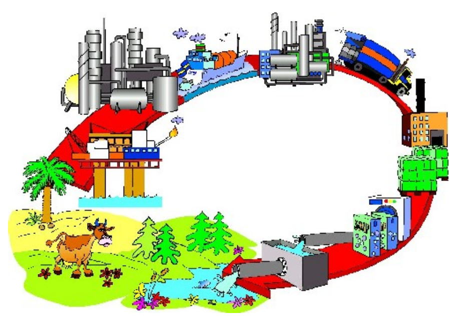
= planning for the future at the level of a **single product** by consideration of material inputs, energy consumption in manufacturing, and environmental impacts at time of disposal.

Design for environment includes the following aspects:
- Design for low-impact materials
- Design for energy efficiency
- Design for servicing and longevity
- Design for disassembly, recycling or composting.

The concept of designing products and processes to minimize environmental impacts is a central element of industrial ecology.

Industrial ecology

= planning for the future at the **company's scale** by consideration of material and energy flows associated with industrial activity.



http://www.dantes.info/Tools&Methods/Environmentalassessment/enviro_asse_lca.html

Frequently industrial ecology focuses on analyzing the life cycle of a particular product from resource extraction, to manufacture (which may involve multiple steps and is often a primary focus of industrial ecology), use (often by individual consumers), and disposal (including recycling).

Sustainable Engineering

= planning for the future at the **global scale**

http://blog.daum.net/film-art/13231852

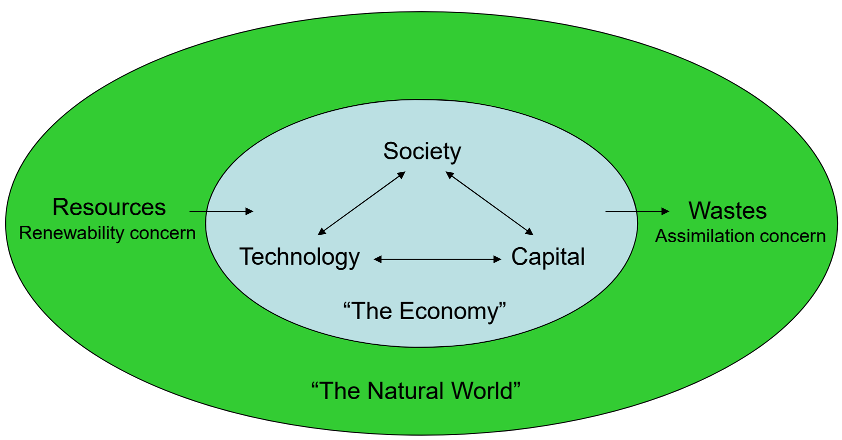
Many believe that a transition to a society supported by sustainable resources is one of the central challenges facing humanity in the 21st Century.

Ultimately, the challenge is to support human society without depleting resource stocks and without accumulating wastes, especially wastes that have a deleterious effect on the environment.

If a transition to reliance on sustainable resources is to occur, it will be the result of the development and deployment of new processes and technologies within the context of an understanding of the interaction between resource utilization, consumption patterns, and environmental carrying capacity.

Sustainable Engineering, cont'd

Necessary to the sustainability objective is a global outlook of the *economy* on one hand and of *nature* on the other. Central concerns include the depletion of non-renewable resources on the upstream side and climate change on the downstream side of our industrial activities.



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Vocabulary of the Industrial Revolution and Sustainability Revolution

Industrial Revolution	Sustainability Revolution
~~Nonrenewable energy~~ Fossil fuels	Renewable energy
Waste	Efficiency
Climate change	Ecological restoration
Consumption	Resource equity
Accumulation	Social and environmental justice
Toxicity, smog, persistent organic pollutants, endocrine disruptors	Green chemistry
Transportation	Accessibility
Concrete hydraulic channels	Low-impact storm water development, rain gardens
Urban heat island effect	Green roofs
Bioaccumulation	Biodiversity
Industrial design	Green design
Gross national product (GNP)	Index of sustainable economic welfare, environmental sustainability index, genuine progress indicator ← Yet to be defined!

Source:
Mihelcic & Zimmerman, 2010

Shift in scope and patterns

20th Century Environmental Issues	21st Century Environmental Issues
Local	Global
Acute	Chronic (= ongoing)
Obvious	Subtle
Immediate	Multigenerational
Discrete	Complex

(*Source*: Mihelcic & Zimmerman, 2010, page iii)

Example of past local problems

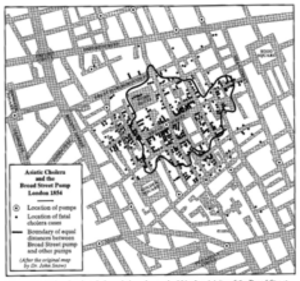


Figure 1.B.1 Map showing cholera victims clustered within the vicinity of the Broad Street pump in London, 1854 (Cosgrove, 1909).

Cholera outbreak in London in 1854. John Snow, medical doctor, tracked the infection to a single well on Broad Street. Solution: He convinced the city officials to remove the pump handle to force residents to get their water from other wells.

Pittsburg in 1906:

Belching smokestacks were then perceived as signs of progress and wealth!

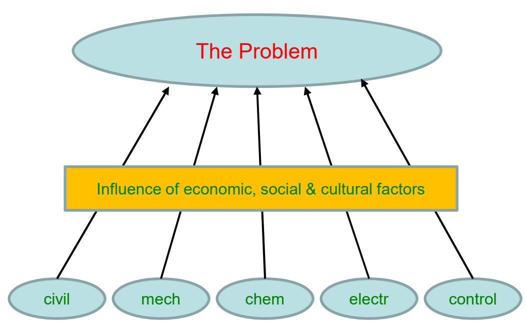
Cuyahoga River (Ohio): It caught on fire in 1952. The cause: oil floating on the surface.

ENVIRONMENTAL ENGINEERING

Environmental Engineering is a discipline of engineering devoted to the development and application of scientific knowledge through technology to eliminate or minimize adverse effects associated with human activities.

It operates at four different levels: remediation of contaminated sites, treatment of effluents, pollution prevention, and care for future generations.

Environmental engineering is fundamentally object-focused, rather than tool-based. It therefore draws from all other engineering disciplines that are apt to bear on the desired objectives. Pursuit of pollution prevention and sustainability further implicate social, cultural and economic considerations, bringing the environmental engineer to collaborate with policy makers and other non-engineers.



ENVIRONMENTAL ENGINEER

The environmental engineer is a professional trained in the art of applying scientific principles and technological means to avoid or reduce forms of pollution by human activities. This includes possessing a knowledge of past and current engineering practice and an ability to innovate.

Further, they are *professionals*, meaning that they are not only applying knowledge but also using judgment and then bearing responsibility for their decisions.

Selection of topics

It is impossible to include all the elements of environmental engineering in a single course.

So, there is considerable judgment involved in selecting topics to address, and it is quite possible that a course entitled *Environmental Engineering* elsewhere might have a different emphasis and address largely different materials.

Thayer School has chosen topics for this course with the following objectives in mind:

✓ Provide a balanced view of the many elements comprising environmental engineering;

✓ Consider selected topics that can be covered to some depth of understanding rather than mention a little bit about everything;

✓ Emphasize topics that can be approached analytically rather than descriptively;

✓ Include forward-looking topics, such as green design and renewable energy.