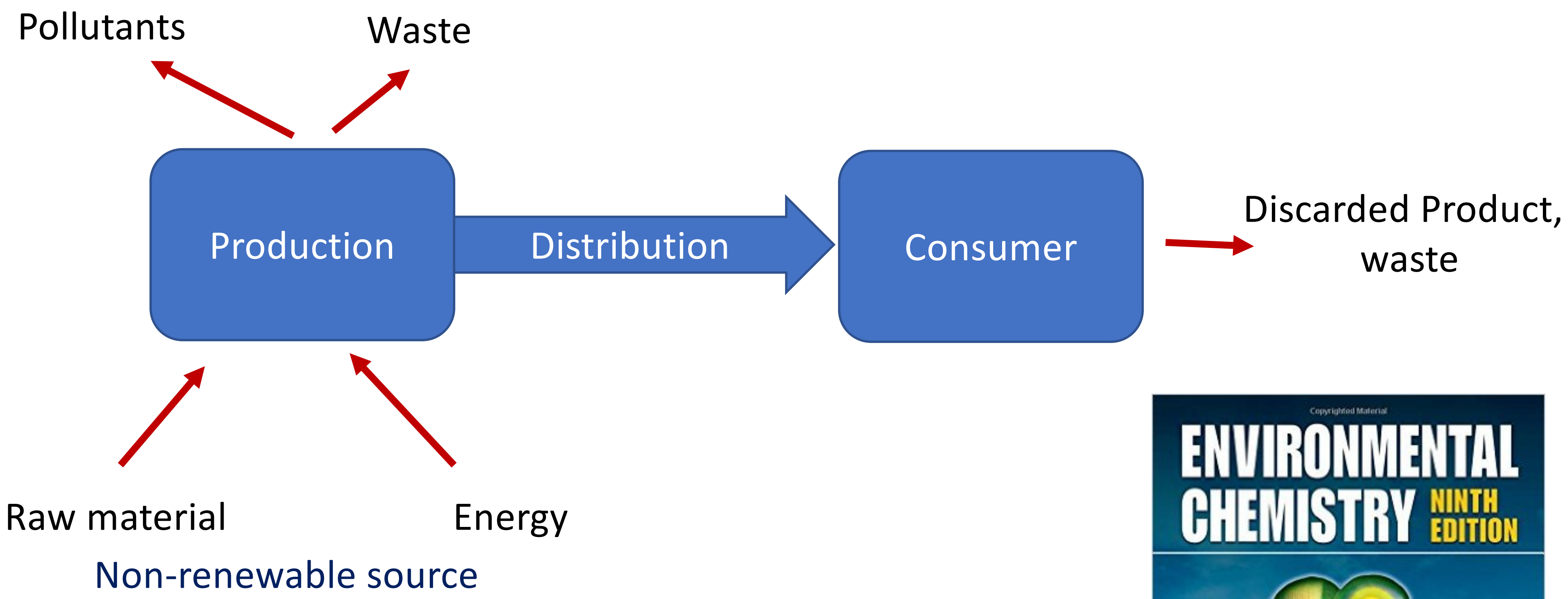
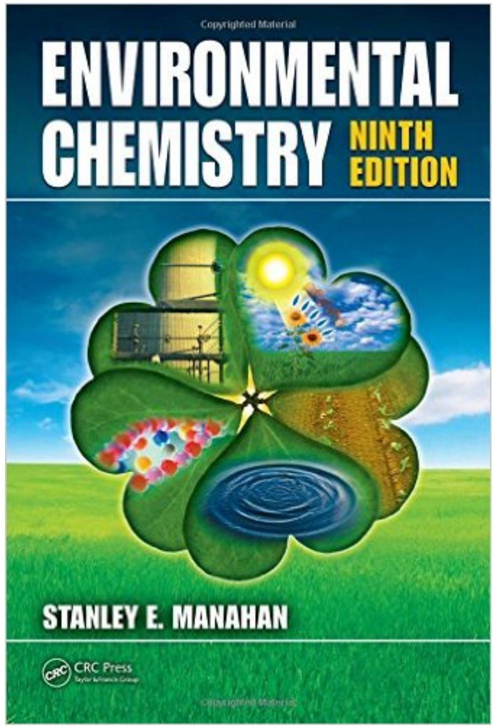
Industrial ecology





Industrial ecology

integrates the principles of science, engineering, and ecology <u>in industrial systems</u>

through which goods and services are provided in a way that minimizes environmental impact and optimizes utilization of resources, energy, and capital

Every aspect of the provision of goods and services from concept, through production, and to the final fate of products remaining after use

$$\frac{\text{Market value of products}}{\text{Consumption of material and energy}}$$

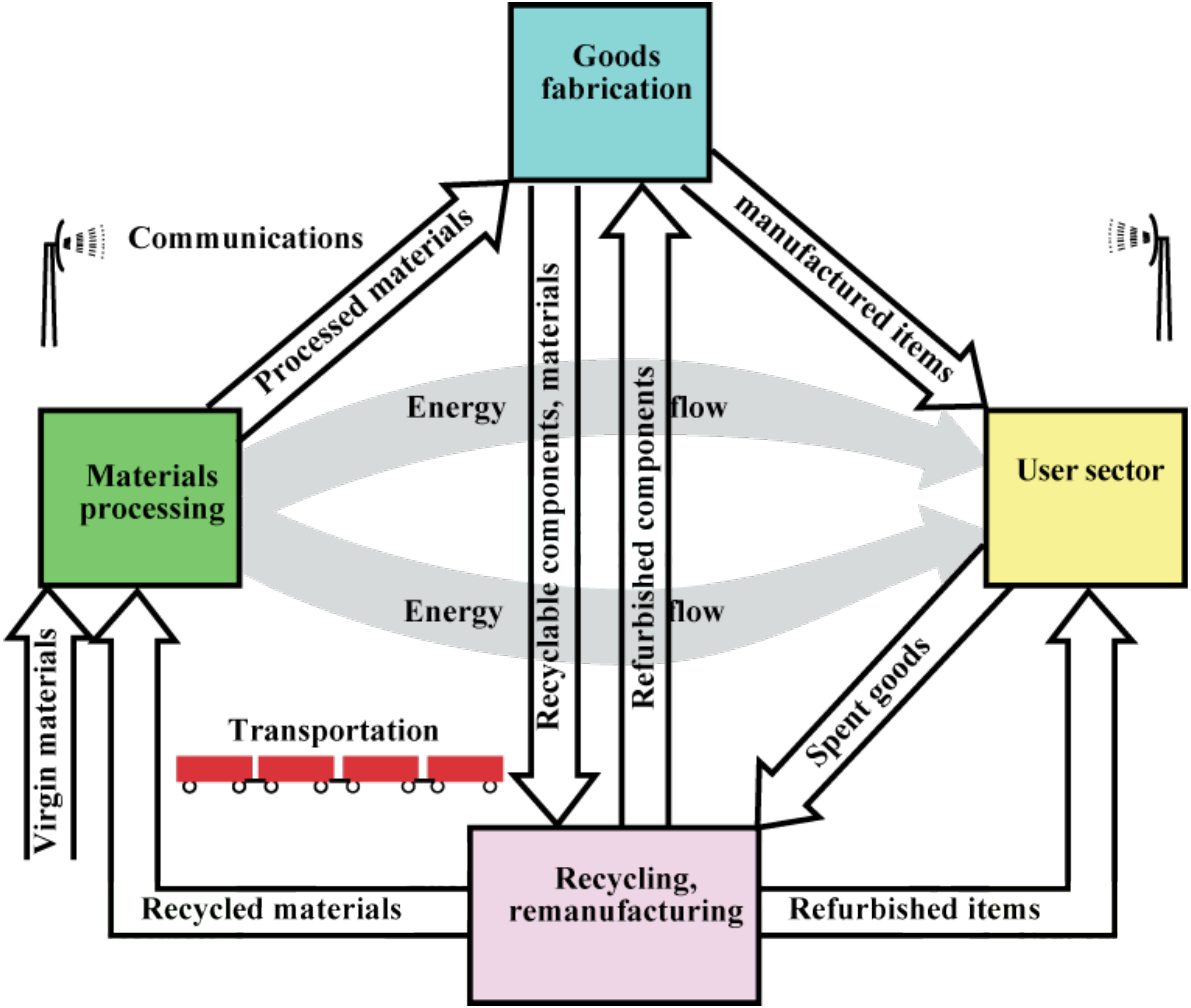
An **industrial ecosystem** functions through groups of industrial concerns, distributors, and other enterprises functioning to mutual advantage, using

each others' products,

recycling each others' potential waste materials,

and utilizing energy as efficiently as possible to maximize

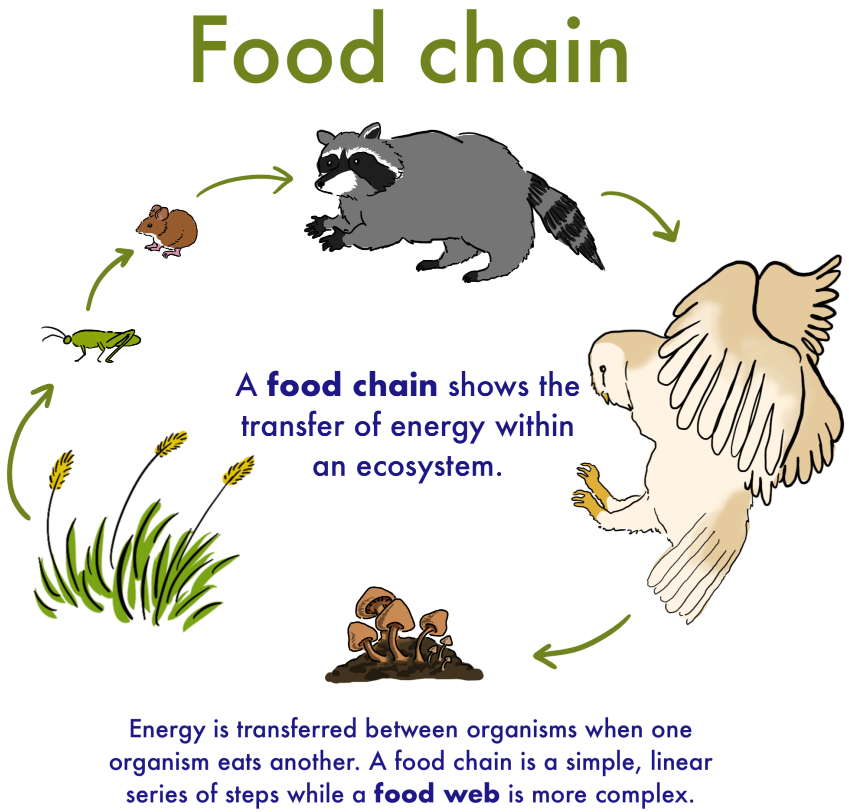
Major Components of an Industrial Ecosystem Showing Maximum Flows of Material and Energy Within the System



Wastes and Industrial Ecology

In natural ecosystems true wastes are virtually nonexistent

Traditional way: Anthropospheric industrial systems have developed in ways that generate large quantities of wastes



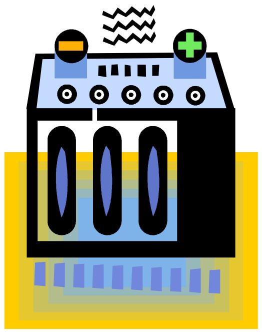
Industrial waste may be defined as *dissipative use of natural resources*.

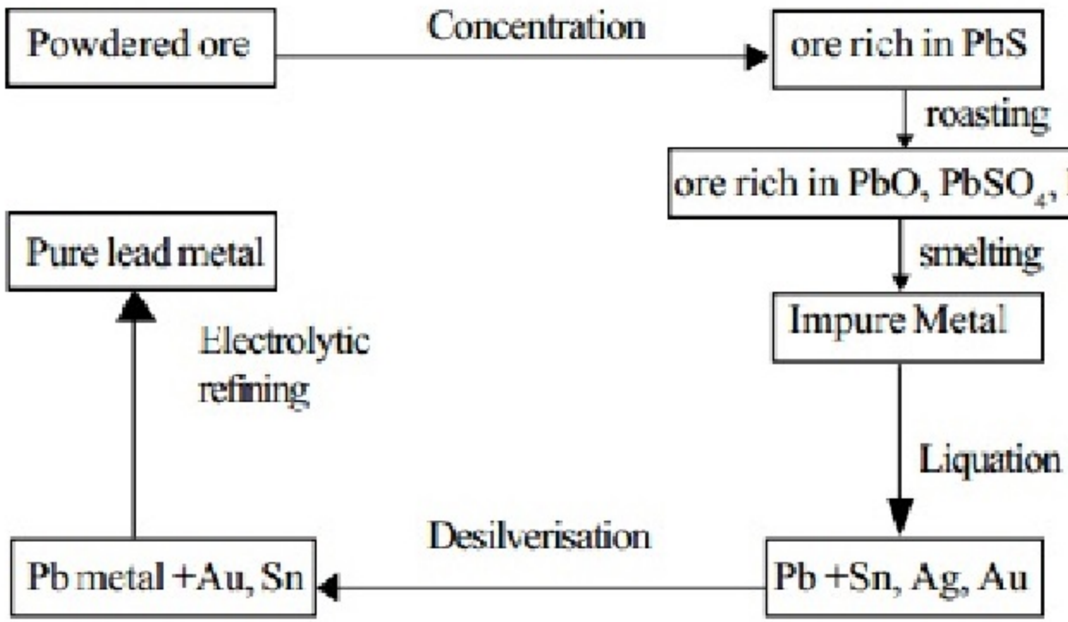
- Human use of materials has a tendency to dilute and dissipate materials and disperse them to the environment
- Materials may end up in a physical or chemical form from which reclamation becomes impractical because of the energy and effort required
- A successful industrial ecosystem overcomes such tendencies

Minimization of Byproduct and Waste

The objective of industrial metabolism in a successful industrial ecosystem is to make desired goods with the least amount of byproduct and waste

Consider production of Pb from Pb-ore for the production of storage batteries





large quantities of lead-contaminated tailings left over from mineral extraction and byproduct sulfur dioxide, (must be reclaimed to make sulfuric acid)

The recycling pathway for lead production takes essentially pure lead from recycled batteries and simply melts it down to produce lead for new batteries

- 95% recycling efficiency

LIFE CYCLES IN INDUSTRIAL ECOSYSTEMS

In a system of industrial ecology the entire **life cycle** of the product is considered as part of a **life-cycle assessment**.

- To determine, measure, and minimize environmental and resource impacts of products and services

Scope of the assessment

- Time period
- Space
- Kinds of materials, processes, and products in the assessment

Example of the manufacture of an insecticide that releases harmful vapors and generates significant quantities of waste material

- A narrowly focused assessment might consider control measures to capture released vapors and the best means of disposing of the waste byproducts
- A broader scope would consider a different synthetic process that might not cause the problems mentioned
- An even broader scope might consider whether or not the insecticide even needs to be made and used; perhaps there are more acceptable alternatives to its use.

Life Cycle Assessment

- **Inventory analysis** to provide information about the consumption of material and release of wastes from the point that raw material is obtained to make a product to the time of its ultimate fate
- **Impact analysis** that considers the environmental and other impacts of the product
- **Improvement analysis** to determine measures that can be taken to reduce impacts

Example of paper product

The environmental impact of paper *product* tends to be relatively low. Even when paper is discarded improperly; it does eventually degrade without permanent effect.

Process of making paper, beginning with harvesting of wood and continuing through the chemically intensive pulping process and final fabrication has significant environmental impact

In doing life-cycle assessments consider three major categories

- **Products**: Things and commodities that consumers use
- **Processes**: Ways in which products are made
- **Facilities** consisting of the infrastructural elements in which products are made and distributed

KINDS OF PRODUCTS

Consumable products such as laundry detergents

Recyclable commodities such as motor oil

Service products such as washing machine

- Consumable products are dispersed to the environment
  - **Nontoxic**
  - Not **bioaccumulative**
  - **Degradable**

- Recyclable commodities should be designed with durability and recycling in mind
  - Not as degradable as consumables

- Service products are designed to last for relatively long times, but should be recyclable
  - Channels through which such products can be recycled
  - Proposed “de-shopping” centers where items such as old computers and broken small appliances can be returned for recycling
  - Designed and constructed to facilitate disassembly so that various materials can be separated for recycling.

REQUIREMENTS BY AN INDUSTRIAL ECOSYSTEM

Energy

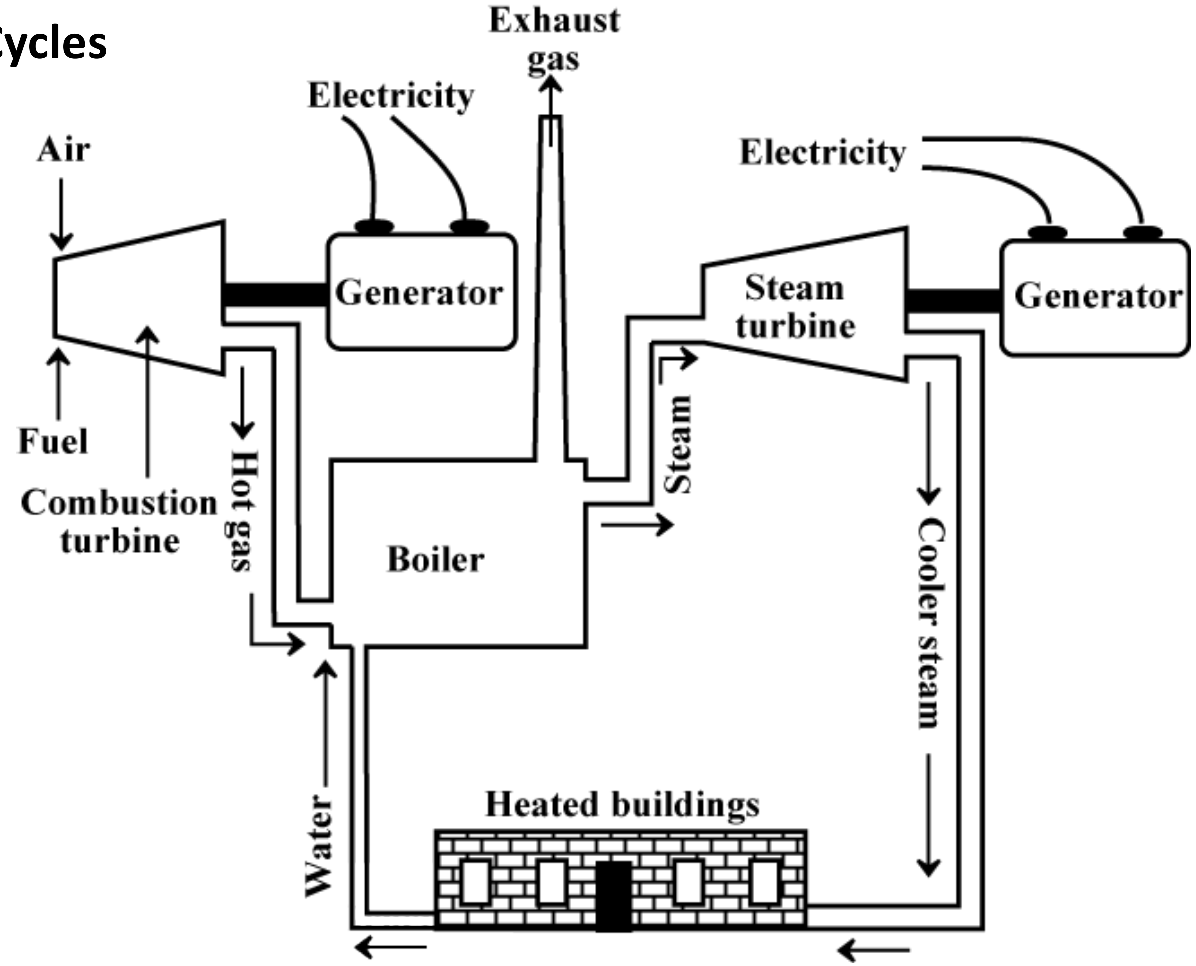
With enough energy, almost anything is possible

- Consuming abundant fossil energy resources would cause unacceptable global warming effects
- Solar energy and wind energy are renewable sources of energy but are intermittent nature and require large areas of land in order to provide a significant share of energy needs
- Nuclear power facilities can provide abundant reliable energy, but present waste problems

Cogeneration and Combined Power Cycles

use energy with great efficiency
through several levels

(1) Electricity generation
(2) Steam used in processing
(3) Steam and hot water used for heating



- Burning fuels in large turbines connected to an electrical generator and using the hot exhaust from the turbine to raise steam can double the overall efficiency of energy utilization.
- Using the cooled steam from the steam turbine for heating can further increase the overall efficiency of the energy utilization process.

Industrial Ecology:

- ❖ Saving resources
- ❖ Recycling
- ❖ Be efficient when possible

Why?

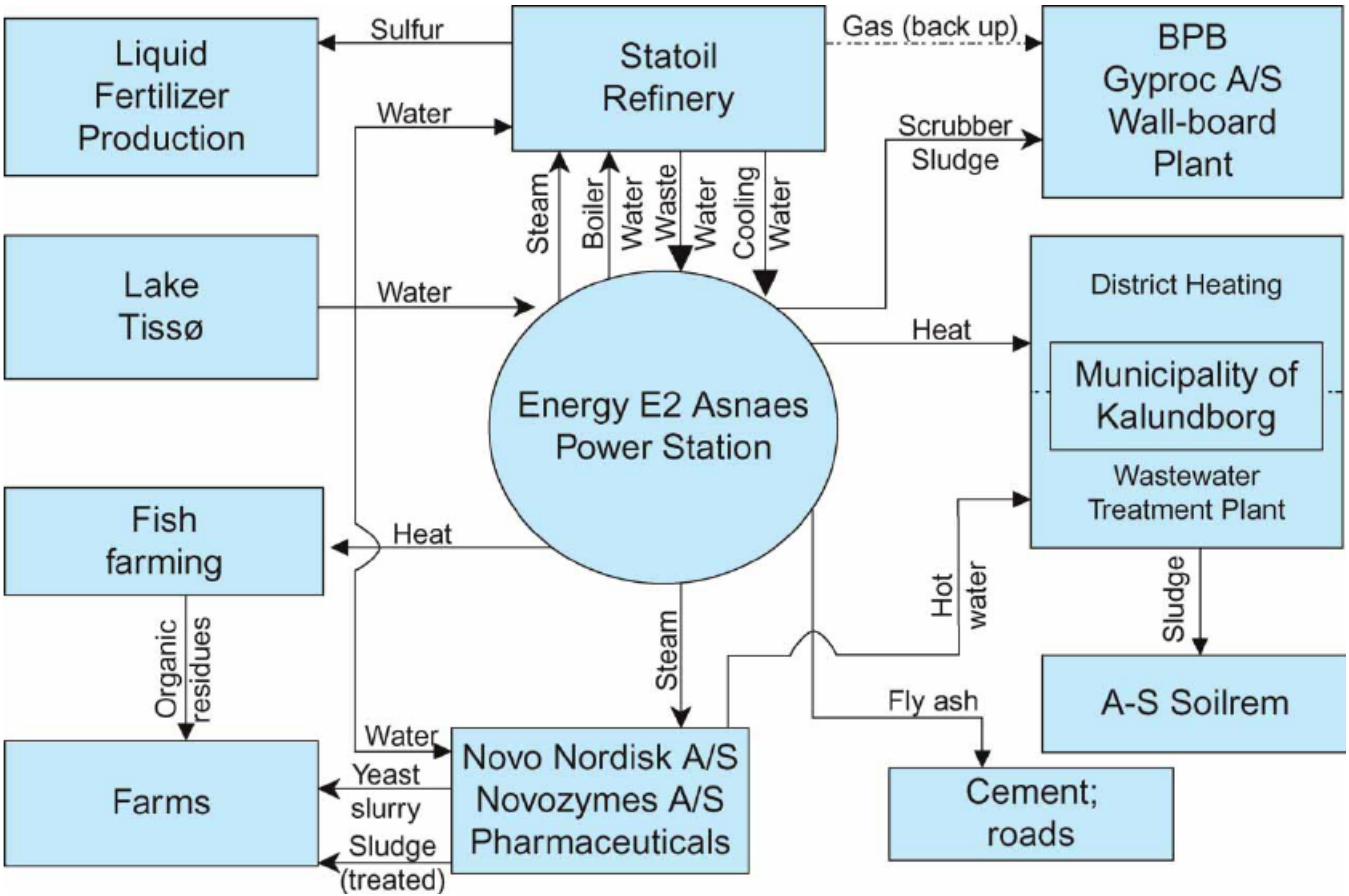
Fewer resources consumed
→ lower operational costs

Less waste/trash
→ lower disposal costs

- Material, water, and energy flows
- Companies within close proximity
- Strong informal ties between plant managers
- Minor retrofitting of existing infrastructure
- One or more anchor tenants.

The most often cited example of a functional inductrial ecosystem : Kalundborg, Denmark

The Kalundborg Industrial Ecosystem



- Saves resources:
  - 30% better utilization of fuel using combined heat + power than producing separate
  - Reduced oil consumption
  - 3500 less oil-burning heaters in homes
  - Does not drain fresh water supplies
- New source of raw materials
  - Gypsum, sulfuric acid, fertilizer, fish farm

Atmospheric lifetime

refers to the duration of time a greenhouse gas remains in the **atmosphere** before being decomposed by chemical processes.

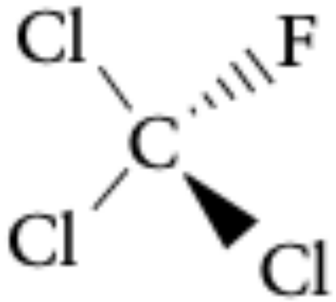
Chloro fuorocarbons (CFCs) and perhalogenated organics

were used for a long time as aerosol propellants, refrigerants, solvents, and foaming agents, **but this use has been curtailed**

So-called halons, which contain bromine as well as fluorines, are still used to extinguish fires in critical situations such as on aircraft.

nontoxic,
stable,
colorless, and
non flammable:

ideal substances for use in a variety of industrial applications



Two major environmental problems,

- ❖ Global warming and
- ❖ Destruction of the ozone layer

Atmospheric Lifetimes and Total Global Warming Potentials of Some Greenhouse Gases (Based on the Atmospheric Composition in 1990)

Gas	Atmospheric lifetime (years)	Time horizon (years) 20	100	500
CO_2		1	1	1
CH_4	10.5	63	21	9
N_2O	132	270	290	190
CFC-11[a]	55	4500	3500	1500
CFC-12[a]	116	7100	7300	4500
HCFC-22[a]	16	4100	1500	510

* $CFCl_3$ = CFC-11

Range of Lifetimes and Ozone Depletion Potentials (ODPs) of Selected Halogenated Gases

Compound	Lifetime (years)	ODP
CFC-11	50	1.0
CFC-12	102	0.82
CFC-113	85	0.90
HCFC-141b	9.4	0.10
HCFC-142b	19.5	0.05
HCFC-22	13.3	0.04
HFC-134a	14	$< 1.5 \times 10^{-5}$
HFC-152a	1.5	0
H-1301	65	12
H-1211	20	5.1
CF_4	>50,000	0
CH_3Br	~ 1.3	~ 0.6
CF_3I	< 2 days	0
HFE-7100	4.1	0

Perfluorocarbons (PFCs)
Since in general they absorb radiation in the near-infrared ``window,'' they are very powerful greenhouse gases

impact of the PFCs on global warming may be greater than 5000 times than that of carbon dioxide 100 years after their release into the atmosphere

a = number of carbon -1
b = number of hydrogen + 1
c = number of fluorine

$CFCl_3$ = CFC-11 or CFC-011

Add 90 to the numerical value

In this case
90+11= 101
def

No. of chlorine= 2d+2-e-f

d = number of carbon
e = number of hydrogen
f = number of fluorine