4. Business, Technology and Manufacturing

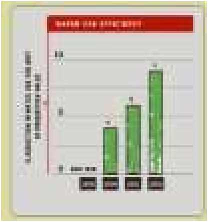
Making business “greener”, and Life Cycle Analysis (LCA)

4.1. Making businesses greener

Four ways to make a business "greener"

1. Increase efficiency
   - Reduces use of natural resources & reduces waste
2. Recycle or re-use elsewhere
   - Recycle within the process, or use as input for other processes
3. Improve quality/extend life
4. Reinvest in natural capital
   - Recycle biodegradable waste
   - Invest money in building & maintaining natural resources

Technology can help with all four!



4.1a. Improving Efficiency

Eco-efficiency

Efficiency which

- reduces or prevents pollution
  - Through good housekeeping, materials substitution, cleaner technologies & processes
- results in more efficient use & recovery of resources

i.e., try to produce more from less!

Design for the Environment (DFE)

A way to achieve eco-efficiency through

A. Cleaner processes
   – Modify to reduce waste
B. Cleaner products
   – Consider full life cycle
C. Sustainable resource use
   – Look at the whole production system and how resources are used.

A. Cleaner processes

Focus on “Pollution Prevention” (P2) or “Waste Reduction At Source” (WRAS)

- Reduce *inputs*- use of energy & materials
- Reduce *outputs*- waste, including air emissions and wastewater streams
- Use technology to aid in the design (e.g. CAD/CAM, computer models, etc.

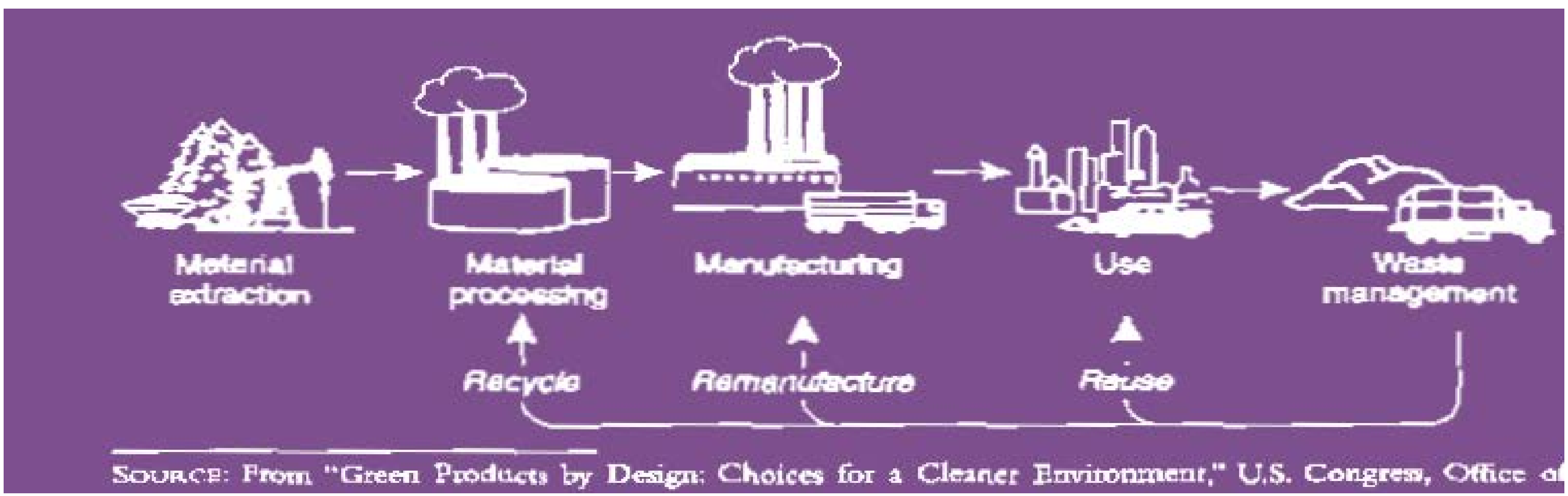
We will cover this topic in depth in Unit 11

Ways to achieve cleaner processes

- Changes in the process itself
  - (e.g. green chemistry)
  - try to reduce cleaning or purification steps
  - change inputs
  - consider continuous flow
- Changes in the plant itself
  - e.g. green engineering
- Consider internal re-use
- Better housekeeping through
  - plant design (e.g. alarms)
  - better control procedures

B. Cleaner "green" products

- "Green" is a relative term- relative to another product it could replace.
- Green products can command a premium in the marketplace (with good eco-labeling).
- To design green products, perform life-cycle assessment (covered in detail later):



C. Sustainable Resource Use

Solar-thermal array. Picture by US Dept of Energy, Public Domain

- If possible use only materials and energy sources which do not deplete natural capital e.g., solar power vs. oil.

4.1b. Recycle or re-use

Recycle or re-use

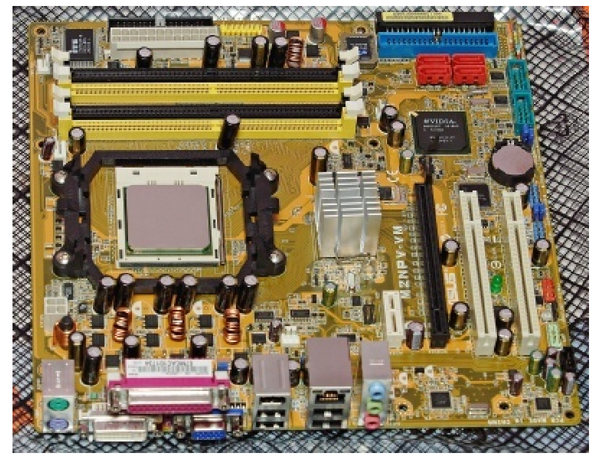
- Much covered under “life cycle analysis.” (later in this unit)
- Need to have good technology for recycling.
- Need to have programs in place for recycling and re-use of materials.

- We will cover this topic in depth in Unit 6

Remanufacture

This involves disassembling and rebuilding a worn-out machine or machine module.

- Already some remanufacturing programs are well established:
  - Toner cartridges (Xerox)
  - Computers (IBM/HP)



Pictures by Håkan Svensson and Fir0002

4.1c. Improve quality & extend life

Product lifetime

- A product with “built-in obsolescence” is inherently wasteful. A product that lasts ten years instead of two reduces environmental impact by 80%.
  - Some modern consumer electrical goods have an expected lifetime of 1-2 years. Victorian steam locomotives were designed to last 50-70 years. Progress?!
- But some products, which impact the environment during use, may need to be replaced by more efficient products to reduce their impact.
  - A steam engine is very inefficient in terms of energy usage!

“Talyllyn” a Welsh steam Locomotive – 150 years old and still running!

Picture by Ken Crosby

Product quality

- Reducing quality problems reduces the amount of product which is rejected, reducing waste.
  - Only 30% of microprocessor chips pass QC tests. What happens to the other 70%?.
  - Any batch of a chemical product which fails to meet specification becomes hazardous waste.

Appropriate technology

- Read pages 101-107 in Dorf (available as PDF under Unit 4 readings).
- Technology should be designed for the locale it is to be used in.
- For the Third World, choose technology which can be locally maintained, requiring low financial capital, & use of human labor.

Picture: Michelle Laurie

4.1d. Reinvest in natural capital

Recycle waste

- For example, waste from the chicken industry is used for making a useful fuel.
- Waste vegetable oil can be used to make biodiesel, suitable for direct use in diesel trucks, etc.

Pictures by helector.gr and cbc.ca

Making products from renewable materials

- Many biomaterials are common and cheap, and underutilized:
  - Soy for packaging
  - Starch for plastics
- Alternatively, new materials may be manufactured (usually by fermentation) from biomaterials:
  - Polyhydroxyalkanoates (PHAs) and polylactic acid (PLA) for strong, biodegradable plastics
- Biotechnology may provide “designer” biomaterials in the future.

- Soy packing peanuts are now commonplace – these are from a cheap, renewable source and fully biodegradable.

Picture: greenasathistle.com

Invest in renewable resources

- A switch to renewable resources can help to preserve natural capital and cause a large reduction in environmental impact.
  - Solar, wind and other renewable energy will reduce greenhouse gas emissions
  - Using renewable materials in place of petroleum/mineral based products

Pictures by [Kit Conn](#) and [greenbuildingblocks.com](#)

4.2. Life Cycle Analysis

(LCA)

Overview of LCA

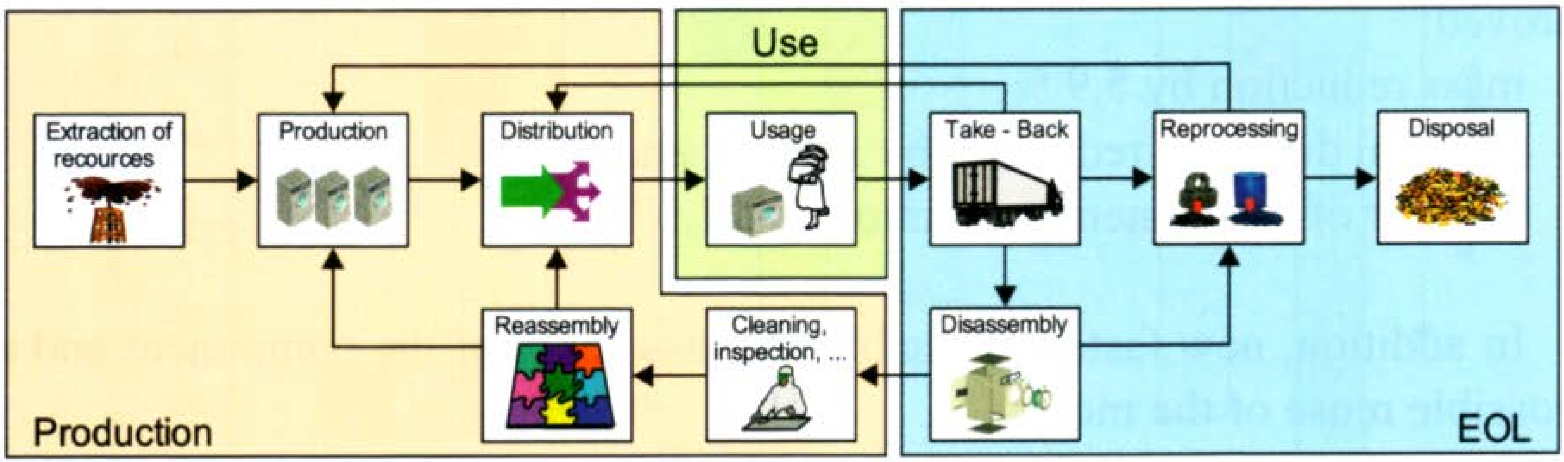


Fig. 3: Simplified product system covering the products' life cycle: Process model according to [26]

From Seliger, p82.

Life-cycle Analysis

- Consider the environmental effects of a product throughout its life.
  - Consider the environmental impact of the materials in waste streams. Biodegradable materials are preferable.
  - Design for disassembly and recycling- need to consider cost of taking the product apart.
  - Choose input materials that are abundant, nontoxic, close to nature and/or recycled.
  - Use full-cost accounting methods.
  - Don’t forget to include packaging, transportation, etc.

A short history of Life Cycle Analysis (1)

- 1960s: Began with US studies on different drink containers, mainly focused on energy usage only.
- Late 1970s: little was done
- 1980s: European debate on packaging reignited interest in LCA. Many govt. studies, but divergent results due to inconsistencies.

How the discussion started!
A 1950s Pepsi delivery truck.
Pic from sizzlinwheels.com

A short history of Life Cycle Analysis (2)

- 1980s-1990s: SETAC (Society for Environmental Toxicology And Chemistry) coordinated research and built a consensus view
- 1990s: Meanwhile ISO developed four standards, ISO 14040-3.*
- Today, these ISO standards form the basis for most LCA analyses.

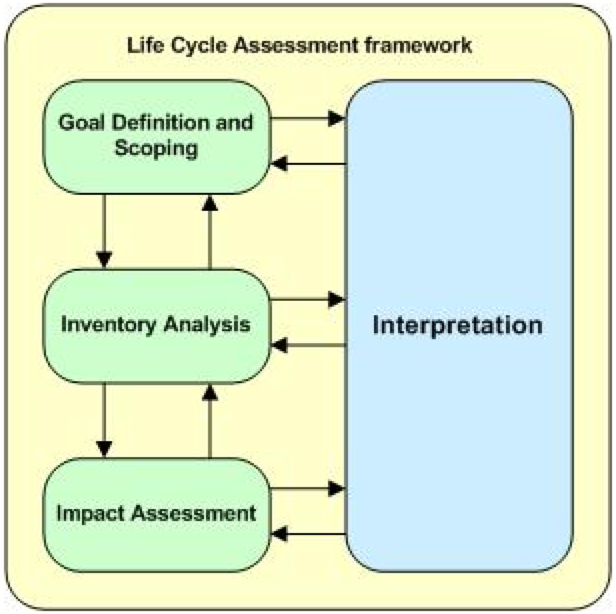
Picture from SETAC

** We will learn much more about ISO 14000 in Unit 10.*

A four stage process

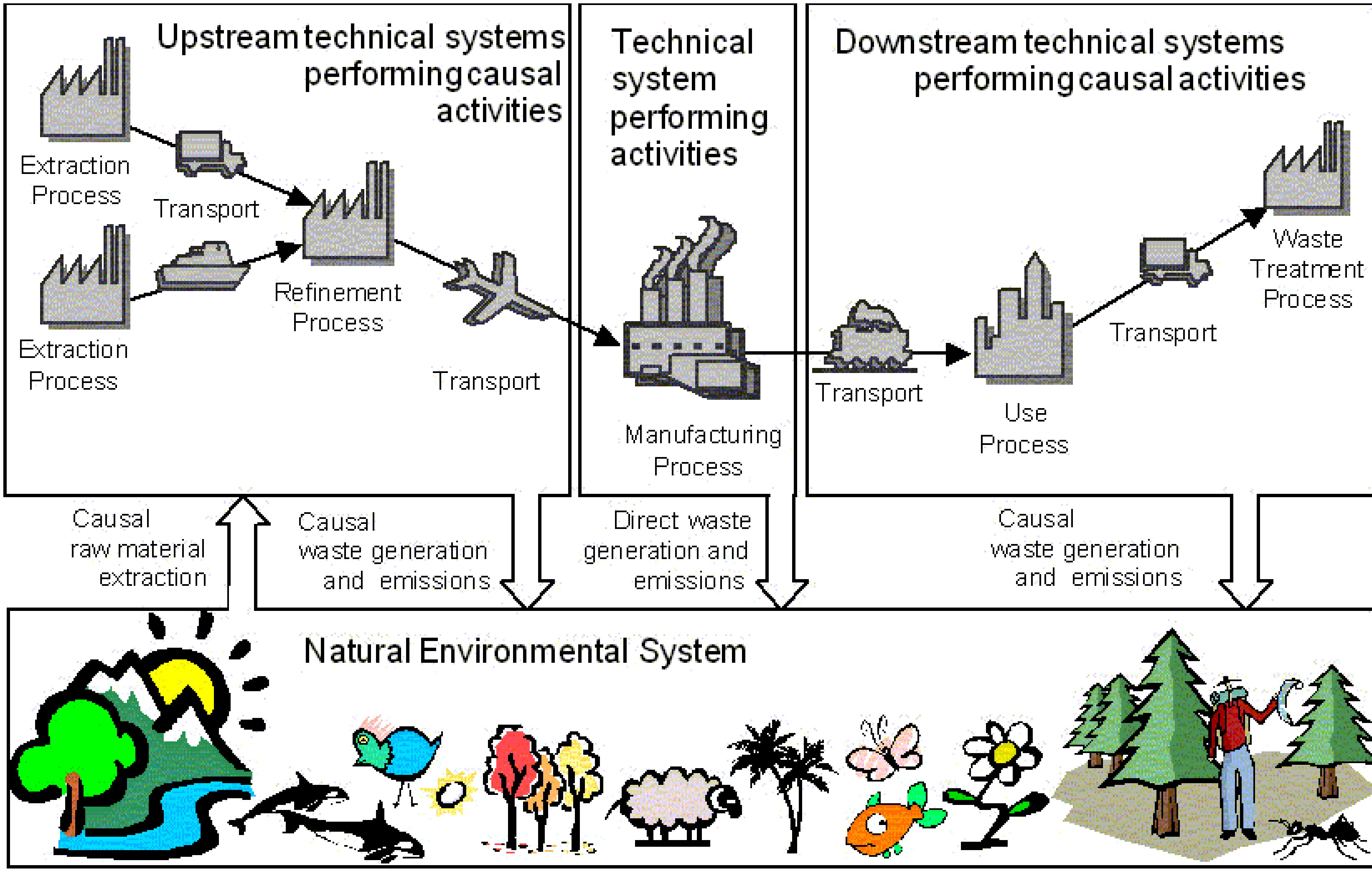
- ISO standards define a four stage process for LCAs:
  1. Goal & scope definition
  2. Inventory analysis
  3. Impact assessment
  4. Interpretation

  The process is then repeated as many times as needed.



Picture from pneuma.enea.it

Life Cycle Analysis



Step 1: Goal & scope definition

Meticulous process to define:

A. What exactly is meant by the “product” or “product system”
B. What does the product have to be able to do in its lifetime?
C. Based on expected conditions for use, what is the expected lifetime for the product?
D. How are these parameters going to be measured and assessed?

Step 1 Example: Household paint

Picture by **Daniel Case**
From WM Commons

A/B. Product definition:

- Coverage and protection of 10 m^2 of wall surface

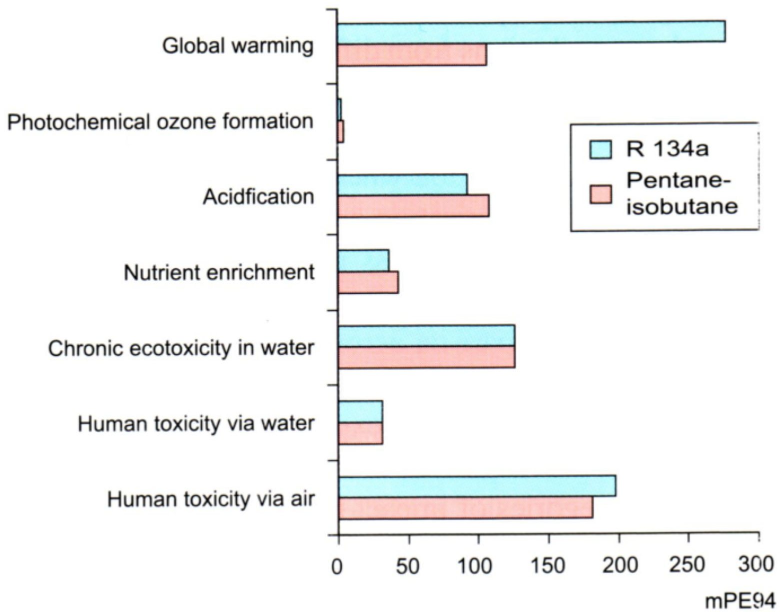
C. Expected lifetime:

- Define this – say five years

D. Assessment parameters:

- Color fastness, given the prevailing climatic conditions and predicted level of sunlight

Step 2: Inventory analysis



From Seliger, Sustainability in Manufacturing, p40

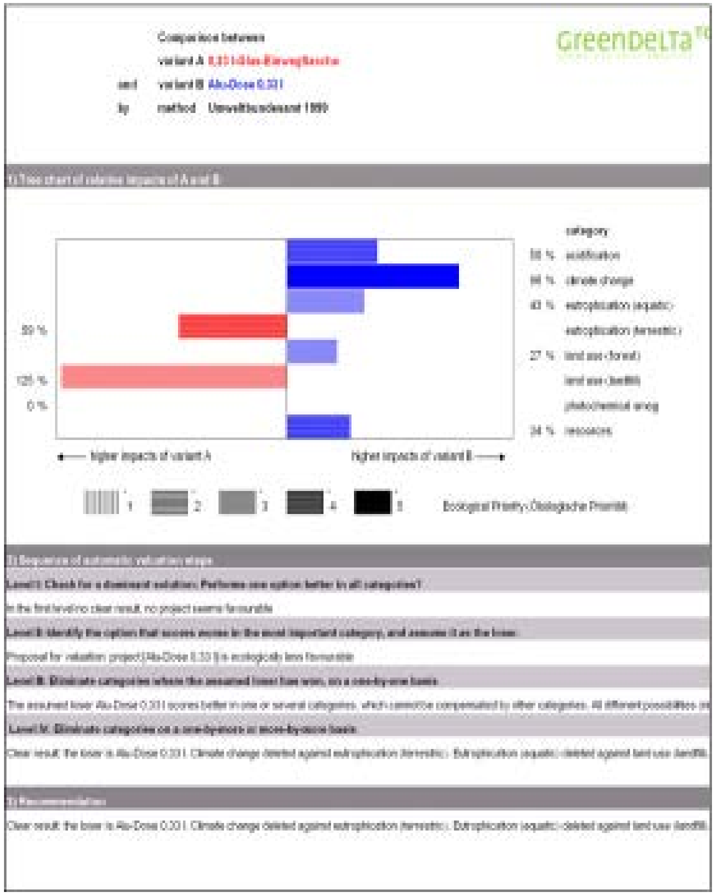
- Examines all processes in the product system
- Collects information on inputs and outputs (e.g., total use of resource A, total emissions of waste B), in terms of the whole system

Step 3: Life Cycle Impact Assessment (LCIA)

- Look at impacts on:
  - Human health
  - Natural environment
  - Natural resources
  - Man-made environment
- Thus it goes beyond simple pollution by toxic materials
- Four steps:
  - Selection of impact categories
  - Characterization (scoring)
  - Normalization between categories
  - Valuation – gives significance of each impact

Step 4: Interpretation

- Used to develop recommendations, by considering
  - Environmental and resource impacts
  - Economic and social aspects
  - Revision of the parameters used, if another study is needed



Picture [from greendeltatc.com]

Conclusion

- Businesses can do a lot to reduce their environmental impact, often without hurting profits significantly.
- Life Cycle Analysis (LCA) provides a useful approach for evaluating the environmental impact of a manufactured product.

Test yourself

- Give an example of how it may be possible to improve the profitability of a process while reducing its environmental impact. The best of both worlds!
  ANSWER =>
- What is remanufacturing? Give an example.
  ANSWER =>
- What is "appropriate technology?" ANSWER =>
- Life Cycle Analysis (LCA) has become a standard method for evaluating environmental impact. What standard guidelines are used, and what are the four steps involved?
  ANSWER =>

GO TO NEXT SECTION =>

GO TO END OF UNIT =>

Answer to self-test

- Give an example of how it may be possible to improve the profitability of a process while reducing its environmental impact. The best of both worlds!
- *The best way to do this is to improve the efficiency of the process involved. Pollution prevention: Look at the waste produced, and redesign the process so it doesn't produce that waste. Waste = money down the drain, so often the result will be a more profitable process!*

<= BACK TO QUESTIONS

Answers to self-test (contd.)

- See Slide 13. Remanufacturing involves taking “waste” products and turning them back into usable products. Example – Kodak “one-use” cameras are sent back to Kodak and remanufactured (also HP computers)
- See Slide 17, and Dorf reading. Technology “designed for the locale it is to be used in.” For example, a pump for use in a remote area cannot rely on electricity from the grid.

- <= BACK TO QUESTIONS

Answers to self-test (contd.)

- ISO 14040 (part of ISO 14000) has become the standard approach for LCA.
- It involves four steps:
  - Goal & scope definition
  - Inventory analysis
  - Impact assessment
  - Interpretation

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4.3. Manufacturing

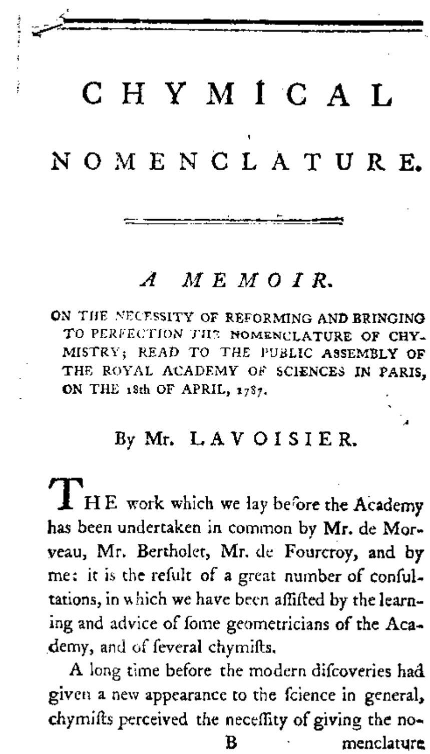
4.3a History of Manufacturing

Early manufacturing

- Stone Age, Bronze Age, Iron Age- the most important materials for manufacturing defined the development of early civilization.
- Early manufacturing largely in "cottage industries," and all work done by hand.
- The Renaissance & Enlightenment helped lead to a Scientific Revolution that laid the foundations of the Industrial Revolution.

Scientific Revolutionaries

- Kepler & Galileo (C16th)- astronomy & physics
- Bacon & Descartes (C17th)- philosophy of science
- Newton (C17th)- physics
- Napier & Newton (C17th)- calculus
- Lavoisier & Dalton (1780-1810)- chemistry



CHYMICAL

NOMENCLATURE.

A MEMOIR.

ON THE NECESSITY OF REFORMING AND BRINGING TO PERFECTION THE NOMENCLATURE OF CHYMISTRY; READ TO THE PUBLIC ASSEMBLY OF THE ROYAL ACADEMY OF SCIENCES IN PARIS, ON THE 18th OF APRIL, 1787.

By Mr. LAVOISIER.

THE work which we lay before the Academy has been undertaken in common by Mr. de Morveau, Mr. Bertholet, Mr. de Fourcroy, and by me: it is the reſult of a great number of conſultations, in which we have been aſſiſted by the learning and advice of ſome geometricians of the Academy, and of ſeveral chymiſts.

A long time before the modern diſcoveries had given a new appearance to the ſcience in general, chymiſts perceived the neceſſity of giving the no-

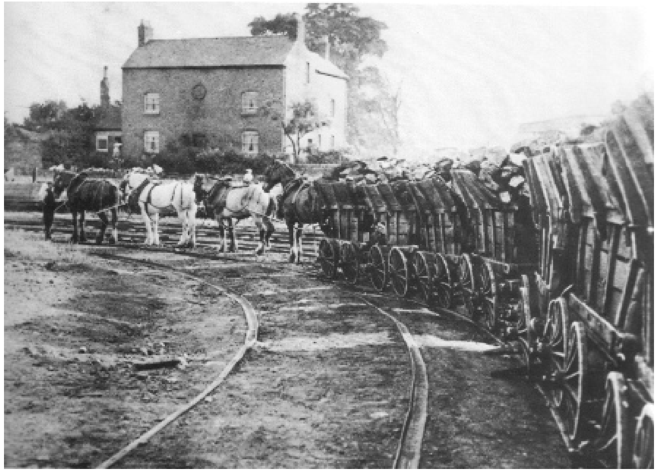
B menclature

Technology milestones

- Thomas Newcomen (1712) & James Watt (1769)- steam power, provided the power for mechanization
- James Hargreaves- Spinning Jenny (1767)- the first large scale manufacturing industry (wool/cotton textiles for clothing).
- George Stephenson- railways, allowed resources to get to factories, goods to reach markets.
- Liebig (fertilizers) & Perkin (dyes) – led to the development of a chemical industry.
- Telegraph & telephone
- Electrical power

Raw materials

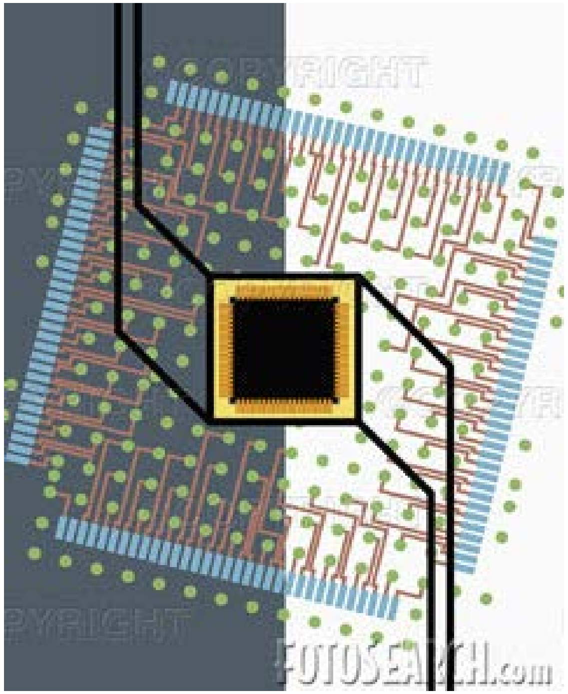
- Meanwhile mining was becoming a large-scale operation using technology such as wagonways (horse-drawn), and later railways (railroads). This led to a booming manufacturing industry for iron, steel, coal and other key materials.



Picture from WM Commons Public domain

C20th developments of note:

- Automobiles & planes
- Mechanization- machine tools, robots, assembly lines
- Construction equipment (bulldozers etc)
- Electrical consumer goods (washing machines, refrigerators, etc.)
- Integrated circuits and electronic goods



More C20th developments

- Computer control
- Plastics and new materials
- The Internet & telecommunications
- Space technology (satellites, etc.)

Then & Now: A comparison

- OLD INDUSTRIES: Produced a material object such as a hat or a refrigerator. Relatively low technology, so raw materials are a significant part of the cost.
- NEW INDUSTRIES: Provide information & services such as a patent searching company or a financial consultancy. No material objects, and little or no raw material usage.

But of course we need both types of industry!

4.3b. History of Manufacturing & the Environment

Early: Earth was vast compared to population

- "Infinite" resources
- "Infinite" capacity to assimilate waste
- Pollution only a local phenomenon

C19th: Cities & factories

- Major pollution seen for first time
- Problems from high population density
- Often factories sited near populations
- Many toxicological effects unknown (mercury, lead, benzene etc.)

Globe Alkali Works near Liverpool, UK ca 1900. Picture from talltalesfromthetrees

After WWII: The modern era

- The environment began to be seen as an asset, connected with quality of life
- First serious questioning of technology: "Silent Spring" (Rachel Carson) on DDT, & the start of the environmental movement (1960s)
- Minamata Bay, Love Canal
- Improvements in chemical analysis and in science allowed connections to be made- the birth of modern toxicology. Allowed long term "chronic" effects (cancers, brain damage) to be understood for the first time, not just short term "acute" effects.
- Beginnings of environmental agencies (US EPA etc.), and concomitant legislation
- Factories situated away from cities, pollution treated before release

1980s to present: Environmentalism goes mainstream

- Consumers now consider environmental impact when purchasing
- Manufacturers forced to adapt to meet legislation & consumer demand- some begin to be proactive
- Green parties in Europe begin to have political influence
- Brundlandt Report, Rio Summit, Kyoto: governments now take sustainable development seriously
- Start of green chemistry, green engineering etc.

4.3c. The Manufacturing Enterprise

Manufacturing

- "The making of goods and articles."
- "A series of interrelated activities and operations involving design, materials selection, planning, production, quality assurance, management and marketing of discrete consumer and durable goods."

Craft Production

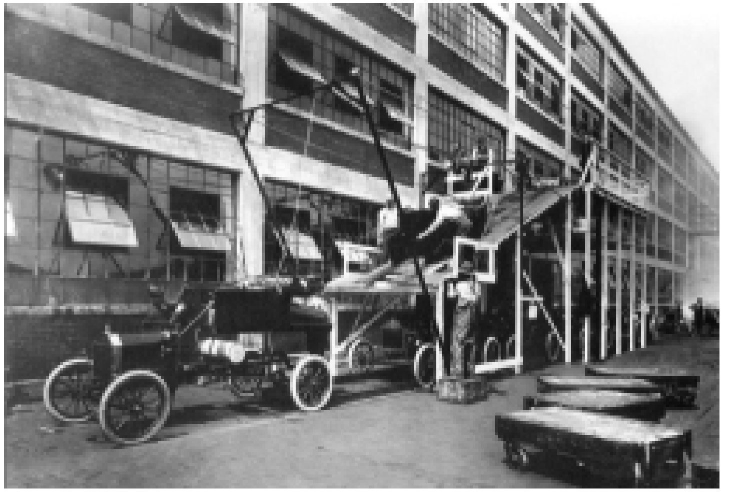
- The traditional method for manufacturing goods.
- Each product is custom-made by hand or with simple tools.

Picture by Tom Allen
from WM Commons, CC license.

- With a skilled craftsman/woman, a craft product can be of higher quality than a mass-produced product. However, handcrafted goods are substantially more expensive than mass produced goods.

Mass Production

- Uses an assembly line to increase productivity.
- Capital intensive, with extensive use of machinery.



1913 Ford production line. Picture by Ford

- Each worker (or robot) performs a simple task (or set of tasks) repetitively.
- Reduces human error, variability, and improves quality and efficiency.
- However, it can be inflexible to changes in product, and the work may be unsatisfying.

Lean Manufacturing

- Based on the successful "Toyota Production System" model for manufacturing, which built upon earlier mass production methods.

Picture: Wikimedia Commons

- It has become a dominant model for large-scale manufacturing.
- The goal is to produce more with less – less waste, less labor, less time, less space, less money.
- A major part is the elimination of all types of waste derived from Toyota's muda, as well as mura (unevenness) and muri (overburden).

Seven deadly wastes (muda)

- Overproduction (production ahead of demand)
- Transportation (moving products that are not actually required to perform the processing)
- Waiting (waiting for the next production step)
- Inventory (all components, work-in-progress and finished product not being processed)
- Motion (people or equipment moving or walking more than is required to perform the processing)
- Over Processing (due to poor tool or product design creating activity)
- Defects (the effort involved in inspecting for and fixing defects)

Sequential vs. Concurrent Manufacturing

SEQUENTIAL

- Break down the manufacturing process into simple steps.
- Simple to plan & execute
- Workers specialize
- Inflexible to change, and hard to introduce new products
- Low worker "ownership" & involvement, feel like part of the machinery.

- CONCURRENT
- "Team" approach- the team performs the *whole* process, in parallel with other teams.
- Harder to plan & organize
- Workers need to be generalists
- Very flexible and accommodating to changes
- Higher worker satisfaction & input

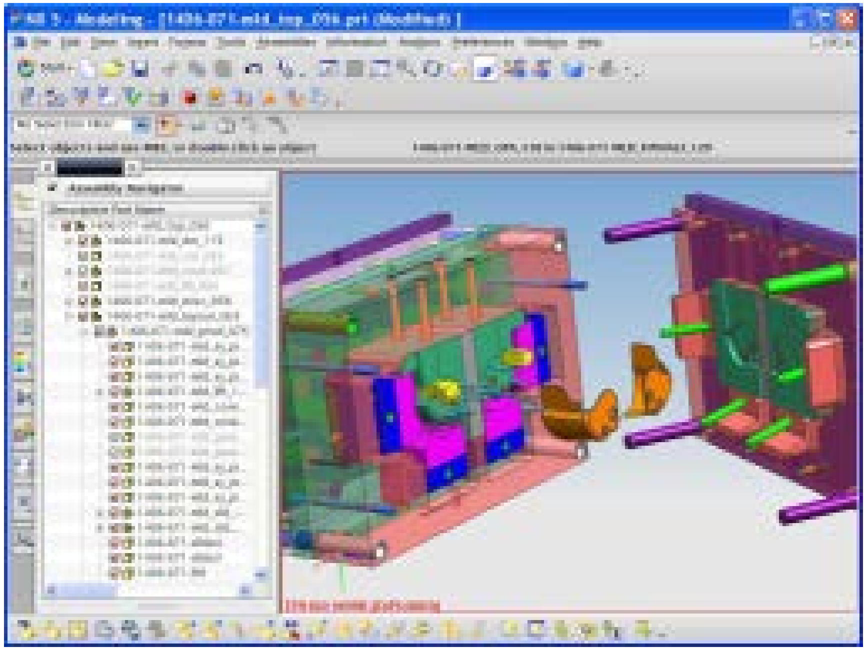
Volvo Uddevalla plant: An experiment in concurrent manufacturing

The Uddevalla Experiment

- In the 1980s, Volvo needed to expand production at a time when the labor market was tight.
- Instead of a production line of with workers performing a single, narrow task, production was based on a small team of workers who would build an entire car. Workers perform a much wider variety of tasks, some skilled, and have the satisfaction of seeing their team's end product. The system was then adopted at the Kalmar plant.
- Workers have a much higher level of "ownership" and so contribute more to product/process improvement. Productivity and product quality was higher than other European plants.
- Economic and political changes led to the closure of this small plant, but **not** because of manufacturing or productivity problems.
- Volvo now operates some of its main plant using an Uddevalla model. This will produce "special vehicles" such as police cars and ambulances, which have many custom features. The Uddevalla method is widely studied, even today.

Computer-aided manufacturing (CAM)

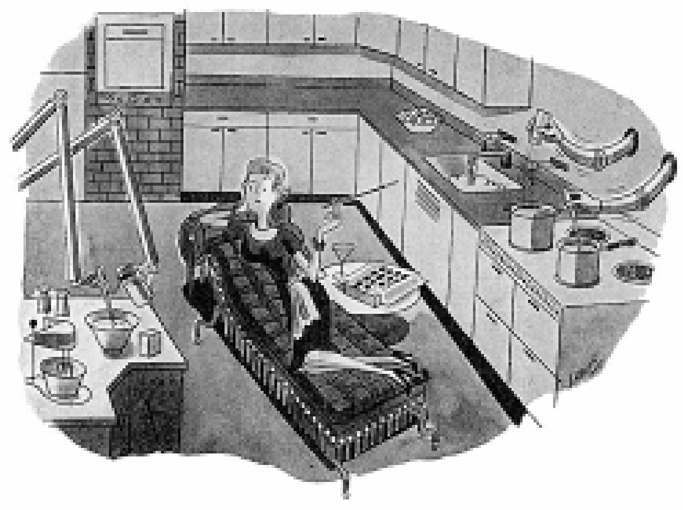
- CAD = Computer-Aided Design
- CAM = Computer-Aided Manufacturing
- Usually linked up as CAD/CAM



Mold-tooling using CAD/CAM.
Picture by **Jerryss**, GNU license.

- If *all* aspects of the manufacturing process are channeled through one common database of information, a single change updates the whole system.

Automation?



- Mechanization- fixed tools, quite inflexible
- Automation- much more flexible but much more expensive at present.

Product Realization – 7 steps to the product

1. Specification development
2. Conceptual design
3. Product design
4. Make or buy?
5. Process design
6. Production
7. Customer feedback

4.4. Quality

A critical issue affecting environmental impact- a poor quality product will have a higher failure rate and shorter lifetime.

Quality

- **Quality Control (QC)**: Analysis of starting materials & products, to check that materials are within the specifications required ("in spec").
- **Quality Assurance (QA)**: Following the "paper trail" to ensure that the correct procedures are followed from raw materials, through the manufacturing process to the final products.

Quality Control (QC)

- *Raw materials* or *parts* are checked to ensure that they are meet the requirements for the process.
- *In-process*: When a process is running, tests may be done to check that things are going right.
- *Final product* testing is critical, the product must meet all specifications required by the customer.

Picture by KY Geologist from Flickr, CC license.

Quality Assurance (QA)

- *Raw materials*: Was the correct paperwork supplied on purity, etc.?
- *In-process*: Was the procedure strictly adhered to?
- *Final product*: Is all of the necessary paperwork ready for the customer and for the carrier? Is the packaging & labeling OK?
- *Validation* of all new procedures is a way to check that these new methods actually give genuine and accurate results, before they are adopted for use by QC.

Checks & balances

- QA acts as a semi-independent check on QC and the production department to ensure that the correct procedures are followed, and that all of the paperwork is filled out correctly. There is pressure on production to make products quickly, and pressure on QC to get things to "pass" quickly- thus QA is needed to make sure that these departments do not cut corners.

ISO 9000

- A set of international standards that lays out standards and methods for a system of quality management. If a company applies for and is granted ISO 9001 or 9002 accreditation, it tells the world (notably customers) that the company is following very rigorous standards for quality management.

Two main categories

- ISO 9001 is for facilities that manufacture a product (e.g. a car factory).
- ISO 9002 is for facilities that merely handle products (e.g., a warehouse).

Six sigma

Picture by Luxo from WP Commons

- A popular system for elimination of defects in a systematic way.
- Pioneered at Motorola, it builds on the ideas of “plan-do-check-act” by W. Edwards Deming, as well as earlier quality improvement methodologies such as Total Quality Management (TQM).
- The goal is to reduce defects below 3.4 per million opportunities. A defect is “nonconformity of a product or service to its specifications.”
- It is based on a continual effort to reduce variation in process outputs using production measurements and controls. It requires that the entire organization be involved.