Material Flow Analysis

(Substance Flow Analysis)

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Life Cycle Value and Cost

- One of the most important concerns is evaluating the **lifecycle cost or value** of a product
- Including currently counted costs (**internal costs**) and currently uncounted costs (**external costs** -- environmental, health and social costs)
- From the first step in making a product until its final recycling or disposal
  - From cradle to grave
  - Or cradle to cradle
- Few products have minimal external costs

Looking at LCCA (remember MIPS)

Pick a common everyday item

- What is the price?
- Where is it made?
- How is it sold?
- What is made out of?
- Who made it?
- What does it require for maintenance
- Where does it go at end of life?
- What are the life cycle costs and benefits?

Also consider

- How is it packaged? (for each part of the package think of possible environmental and social costs)
- How is it maintained? (for each of the materials used think of possible environmental and social costs)
- How long will it last if well maintained? If abused and neglected?
- How is it disposed of or recycled? (think of possible environmental and social costs)

Impacts

- A= air pollution, W =water pollution, X = toxics, E = ecosystem damage, H =health costs, S =social costs, add *transportation costs between all steps*

A	W	X	E	H	S

Material gathering

Material processing

Manufacturing

Distribution (losses)

Sales

Use

Maintenance

Disposal

It depends

- One of the challenges is the wide difference possible for a given product
- A cotton shirt might be made with naturally colored cotton, raised on an organic farm by well paid labor, and sewed in a cooperative providing a good wage and benefits
- Or it could be made in a sweatshop with cotton grown on a chemical intensive farm, bleached with chlorine, colored with toxic dyes and no pollution control equipment
- Ultimately labels may tell us!
- Perhaps RFID chips

The Tip of the Iceberg

- On the average, industrial products carry non-renewable footprints that are about 30 times their own weight
- This means that only about 5% of the non-renewable natural material disturbed in the environment typically end up in a technically useful form
- The 25 kg we throw out each week probably represents 750 kg of waste and material disturbed
- In the case of a PC, the environmental (abiotic) footprint weighs at least 200 kg per kg of product

True Cost Accounting

- Material flow analysis is critical in developing accurate and complete costs
- Health issues can be related to material flows, hazards, and impact
- Ecosystem impacts of materials may be very serious even for materials that appear harmless

The iceberg

- Most of our wastes are made far away and are not noticed
- The coal fired power plant that generates our electricity may damage ecosystems and kill people in Arizona or Colorado--but we don’t see it

Material intensity per service

Wuppertal Institute
(footprint factors):

- round wood = 1.2
- glass = 2
- plastics = 2-7
- steel = 7
- paper = 15
- aluminum = 85
- platinum = 500,000

Systems considerations

- For electricity delivered to the German grid brown coal was 50 times as material intensive as wind powered or natural gas, and 8 times as intensive as photovoltaic cells
- Every country should develop and maintain MIPs accounts
- A company might do well to develop MIPs for products and services and to use MIPs in evaluating new products and services

LCCA

- A **life cycle cost or value assessment** tries to develop an accurate picture of all the benefits as well
- A flow chart can help portray the life cycle
- The EPA has developed a program called TRACI and maintains a web site with LCCA materials
- A number of other programs are available worldwide, SIMAPro, Eco4.0, Team 4.0, LCAit, GaBi, EPS2000 and others can be purchased. Many have a free trial.
- Ecological impacts are very little studied

Challenging but possible

- A detailed LCCA or LCVA requires research and critical thinking
- For each component of a product an assessment of the environmental benefits and cost is done
- Even for something simple like a bar of soap this entails considerable work and knowledge
- In many cases basic research would be needed to develop and accurate picture of LCC
- Both health and ecosystem responses to many materials are poorly understood

Simply Soap

THE SOAP

TALLOW - FROM ANIMAL FAT (ranches, meat packing, rendering, etc.)
LYE - FROM ELECTROCHEMICAL TREATMENT OF SALT (sodium hydroxide, caustic)
CHEMICALS, PERFUMES, ENERGY, WATER, ETC.

THE BOX/PACKAGING

TREES AND CLAY FOR PAPER, ENERGY AND CHEMICALS (chlorine) TO PROCESS
OIL AND ENERGY AND CHEMICALS AND CATALYSTS TO MAKE PLASTICS
ENERGY, WATER
PIGMENTS AND OILS FOR PAINTS AND INKS

TRANSPORTATION

MINING, PROCESSING, MANUFACTURING, MAINT., USE

DISPOSAL

SEWAGE, LANDFILL, RECYCLING, ETC.

Complex soaps

- More complex soaps would have many more impacts
- Ingredient lists may list 10-20 chemicals
- If they add anti-bacterial chemicals the health risks may go up instead of down
- These can help create super-bugs that are very hard to kill

MFA as part of LCCA

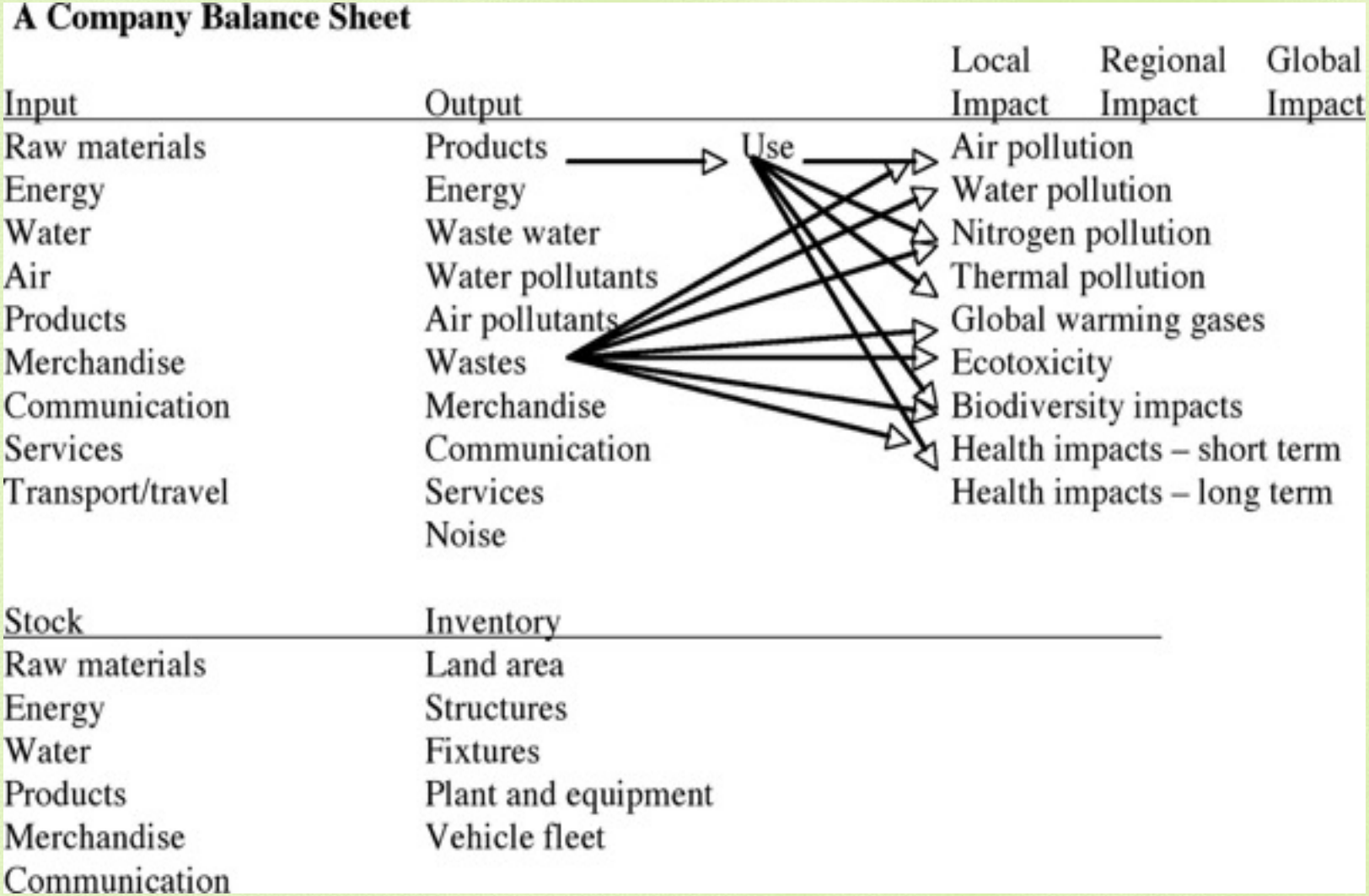
- To understand Life cycle costs and value we need to know where things go and what impacts they cause
- Material flow analysis is a critical component of these studies

MFA

- Where does it come from?
- Where does it go?
- What does it do?
- What does it cost?
- A not so simple book-keeping problem

MFA Diagram

A Company Balance Sheet



Key MFA Issues

- Even simple materials like nitrogen and phosphorus can cause many ecosystem problems, but we are more concerned with human health
- Key materials that need better analysis include: antibiotics, hormones and hormone mimics, cadmium, zinc, methyl bromide, fire retardant, pesticides, persistent chemicals, anti-stain chemicals, and nano-particles

Antibiotics

- 270 million antibiotic prescriptions in 2015 (2.5 times the rate in Sweden)
- 18.4 million pounds of antibiotics useful in humans for animals--most non-therapeutic
- Sweden banned all non-therapeutic use of antibiotics in agriculture in 1986
- Millions of pounds of pharmaceuticals are thrown away every year - often washed down the drain and in to water treatment or water bodies

Estrogen

- Impacts noted on fish, otters, other organisms
- Intersex problems - neither male or female
- Reduced sperm counts
- More direct impact than hormone mimics
- Unintended consequences of birth control pills

Hormone mimics

- More than 70 chemicals identified
- These affect sex characteristics (almost all fish in some rivers are now female)
- Behavior
- Reproduction

Cadmium

- 2060 tons year
- nickel-cadmium batteries (portable power tools), 21 g Cd in a D cell, fortunately being phased out by Ni-MH, lithium and lithium ion batteries
- the NiCd battery market sales volume decreased from 2006 through 2016 by 3% per year
- Affects brain/behavior

Zinc

- 8 million metric tons produced in 2018
- Ecotoxic, esp. to aquatic ecosystems
- Roofing, metal rust proofing
- Very highly dispersed and ubiquitous

Flame retardant

- Widely used to reduce risk from furniture, clothing, bedding, electrical components
- Polybrominated diphenyl ether (PBDE) was banned in Europe in 2004, California 2008
- PBDEs found in all U.S. coastal waters (2009)
- Now in everyone's blood
- Concern is rising
- Substitutes not well studied, DECA causes hyperactivity in mice

Pesticides/biocides

- US uses more than 1 billion pounds year, 700 million pounds in agriculture
- They come back to us on our food - more on fruits, but plenty on vegetables
- Extensive pollution problems with surface and groundwater
- in 2016, 322 million pounds of pesticides used in the US were banned in the EU

Atrazine

- 70 million pounds per year US
- Found in 30% of community water and 60% of private wells in the Midwest
- Health impacts not well studied
- Significant ecosystem impacts
- In 2019 the U.S. Environmental Protection Agency (EPA) announced it would allow 50 percent more atrazine in the surface water along the nation's waterways

Roundup

- Herbicide -- 15-20 million pounds year for farming
- Now Roundup-ready crops (pour it on)
- 4-6 million pounds for home and other uses
- *$1.5 billion in annual income for Monsanto*

but led to a 2020 $10 billion dollar settlement by Bayer (who bought Monsanto) with 50,000 plaintiffs with cancer

U.S. survey--presence in fat

- DDT 100% insecticide Ban 1972
- Dieldrin 95% insecticide Ban 1987
- Chlordane 97% insecticide Ban 1988

Vinyl chloride

- In thousands of products
- Health risks in production and disposal (less impact in use)
- Pipes, siding, windows, car parts, furniture, plastic bags in medicine, etc.
- Burning can yield dioxin (extreme hazard)

Pthalates

- Plasticizer to keep plastics flexible
- Very commonly used until 2008
  - Europe 1999 emergency ban, 2005 more complete restrictions (in 2004 the blood of all 39 parliament members tested in Europe contained pthalates)
  - Calif. ban on children's products 2007
  - US 2008
- Substitutes not well understood--may be more hazardous

Bisphenol & BDE47

- One type of polybrominated diphenyl ether, BDE-47, was found in the serum of nearly all of US participants.
- CDC scientists found bisphenol A in more than 90% of the urine samples representative of the U.S. population.
- Bisphenol A (BPA), a component of epoxy resins and polycarbonates, may have potential reproductive toxicity. General population exposure to BPA may occur through ingestion of foods in contact with BPA-containing materials.

Cooking coatings

- Most people had perfluorooctanoic acid in their blood
- (PFOA) *polytetrafluoroethylene* is used to create heat-resistant non-stick coatings in cookware
- When allowed to get too hot it produces a gas that is often fatal to pet birds

PCBs

- Largely a relict pollutant (first partial bans in 70s)
- 4 billion pounds produced
- Still entering water bodies and ecosystems from old deposits in soil, sediment and organisms
- Distributed all over the world
- Persistent organic pollutant (POP)
- A key problem for Inuit/Inupiat--mothers breast milk and body tissues levels are classified as “hazardous waste”
- See “Silent Snow” by Marla Cone

Nano-particles

- A rapidly growing industrial sector
- Very little studied for health and ecosystem damage
- Grave concern in many circles that they may cause problems -- perhaps like asbestos in some ways
- The miracle fiber....

Microplastics

- Breakdown of plastic leads to trillions of micro plastics
- Now found in sea food
- Ever present in the environment
- Health impacts for humans suspected

Flow analysis

Scales might include:

- Home
- Business
- City
- State
- Country
- Industry
- World

How much?

- Examine records to see
- Bills
- Purchasing
- Government records
- Trade - export import
- International organizations

From where?

- Factory records
- Sales of precursor chemicals
- Purchasing
- Manufacturing reports
- Industry statistics
- Government statistics

Where does it go?

- Corporate records, municipal or agency data
- Water and air monitoring
- Sewage data
- Land fill data
- Soil data
- Health data
- Biomonitoring of fish, shellfish, etc.

What are the impacts?

- Health effects?
- Short term (acute) and long term
- High level and chronic
- Hormone mimic?
- Ecotoxicity?

How do you fund MFA?

- A use fee
- Perhaps $1 per pound for pesticides
- Perhaps 10¢ a gallon for gasoline (hundreds of millions of dollars for California alone)
- That would bring in several billion a year for the U.S. for research, education, monitoring and cleanup

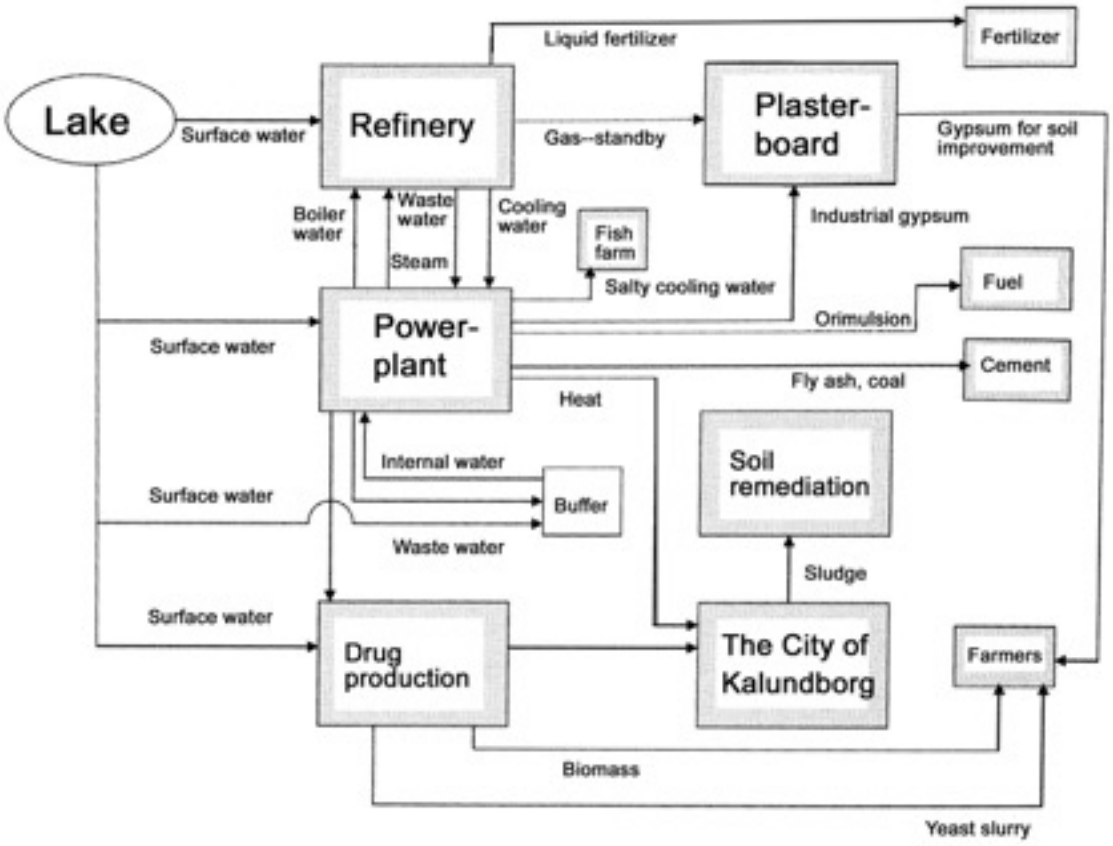
Work Needed

- What we need to do is pressure our politicians at regional, state and federal levels to start this critical work
- Industries should focus on their own issues and develop their own MFA
- International work is also essential

The solution

- True cost accounting
- Be cautious - the precautionary principle
- Remember - there is no away
- Think like nature
- Close the loop of material use

Industrial Ecosystems



Industrial Ecosystem - Sweden

Resources

- **Practical handbook of material flow analysis** P. H. Brunner and H. Rechberger. Lewis Publishers, CRC Press
- **Product design for the environment: a life cycle approach**. By Fabio Giudice, Guido La Rosa, Antonino Risitano Edition. CRC Press
- **Design for the Real World**. V. Papanek
- The International Journal of Life Cycle Assessment
- Journal of Industrial Ecology
- Journal of Cleaner Production
- Global Reporting Initiative www.globalreporting.org