Industrial Ecology, Eco-industrial Park, Networking of Industrial Waste Resources

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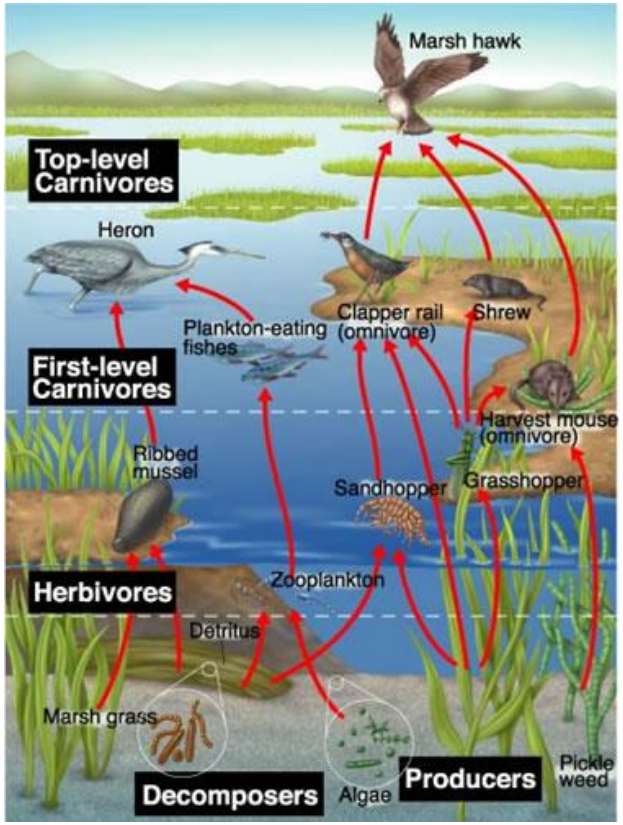
Department of Humanities, Environment & Information Technology
University of Technology of Troyes, France

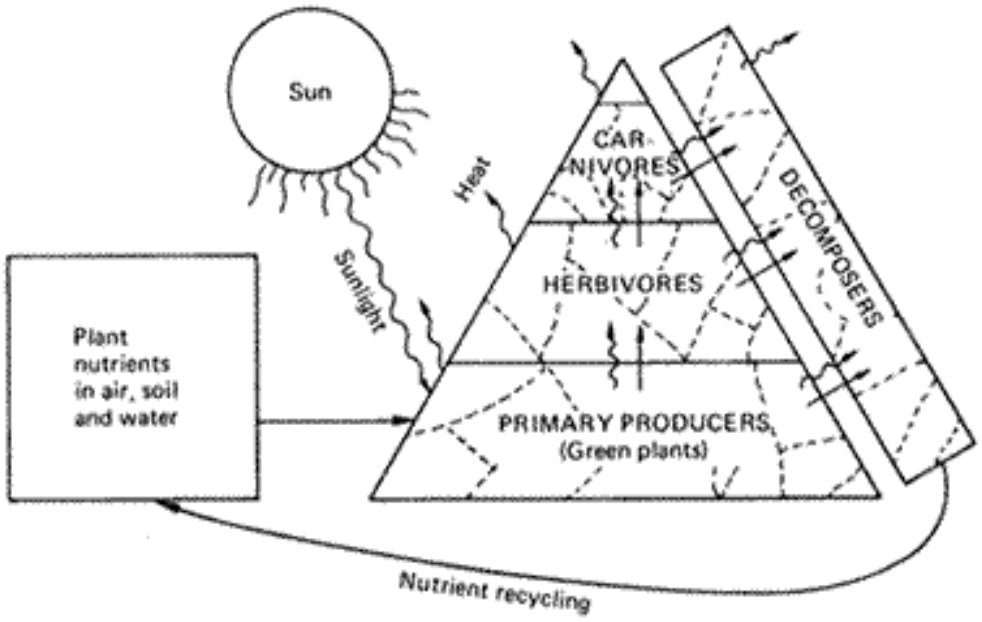
Industrial Ecology ??

Ecology System?
What kind of characteristics and components?

Ecology System (Ecosystem)

- "an interaction among different species in an ecosystem that where they live in a close association with each other"
- Circulation in food chain and web, no waste and pollution etc.



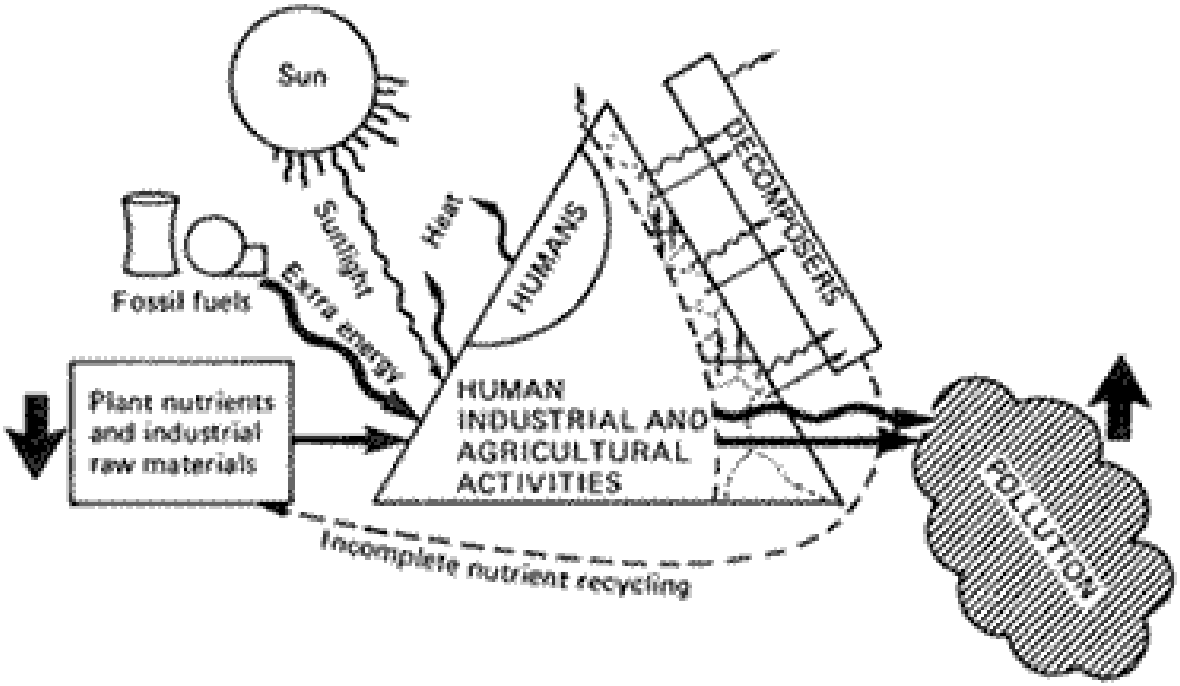


http://telstar.ote.cmu.edu/environ/m3/s5/all_eco_sys.html

How about Industrial System? What kind of characteristics and components?

Ecology of an industrial economy

"why would not our industrial system behave like an ecosystem, where the wastes of a species may be resource to another species"

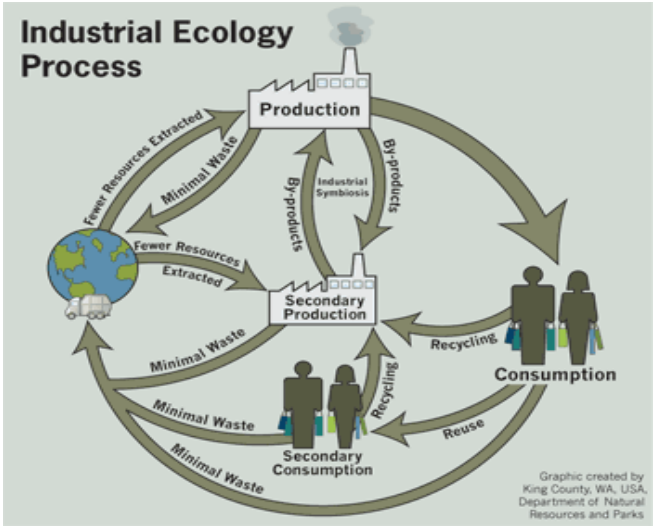


http://telstar.ote.cmu.edu/environ/m3/s5/all_eco_sys.html

Industrial Ecology

In Industrial Ecology (IE) research, we are trying to adopt and apply the ecology system concept to industrial system (to make circular system)

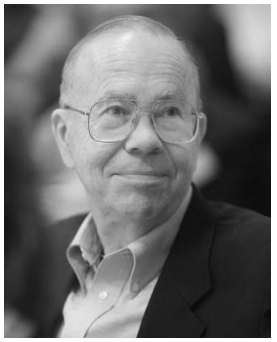
IE is the study of material and energy flows through industrial systems. The global industrial economy can be modeled as a network of industrial processes that extract resources from the Earth and transform those resources into commodities which can be bought and sold to meet the needs of humanity. (Frosch; Gallopoulos; Allenby; Graedel)

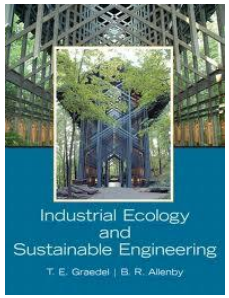


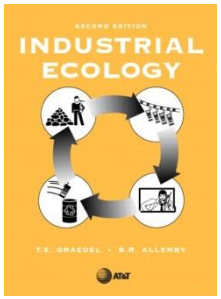
Defining Industrial Ecology 2015
- The science of the circular economy
- The science behind sustainability
- The field that quantifies the Anthropocene

(Thomas Graedel, Yale University)

https://www.youtube.com/watch?v=1_xiFi9oZCc







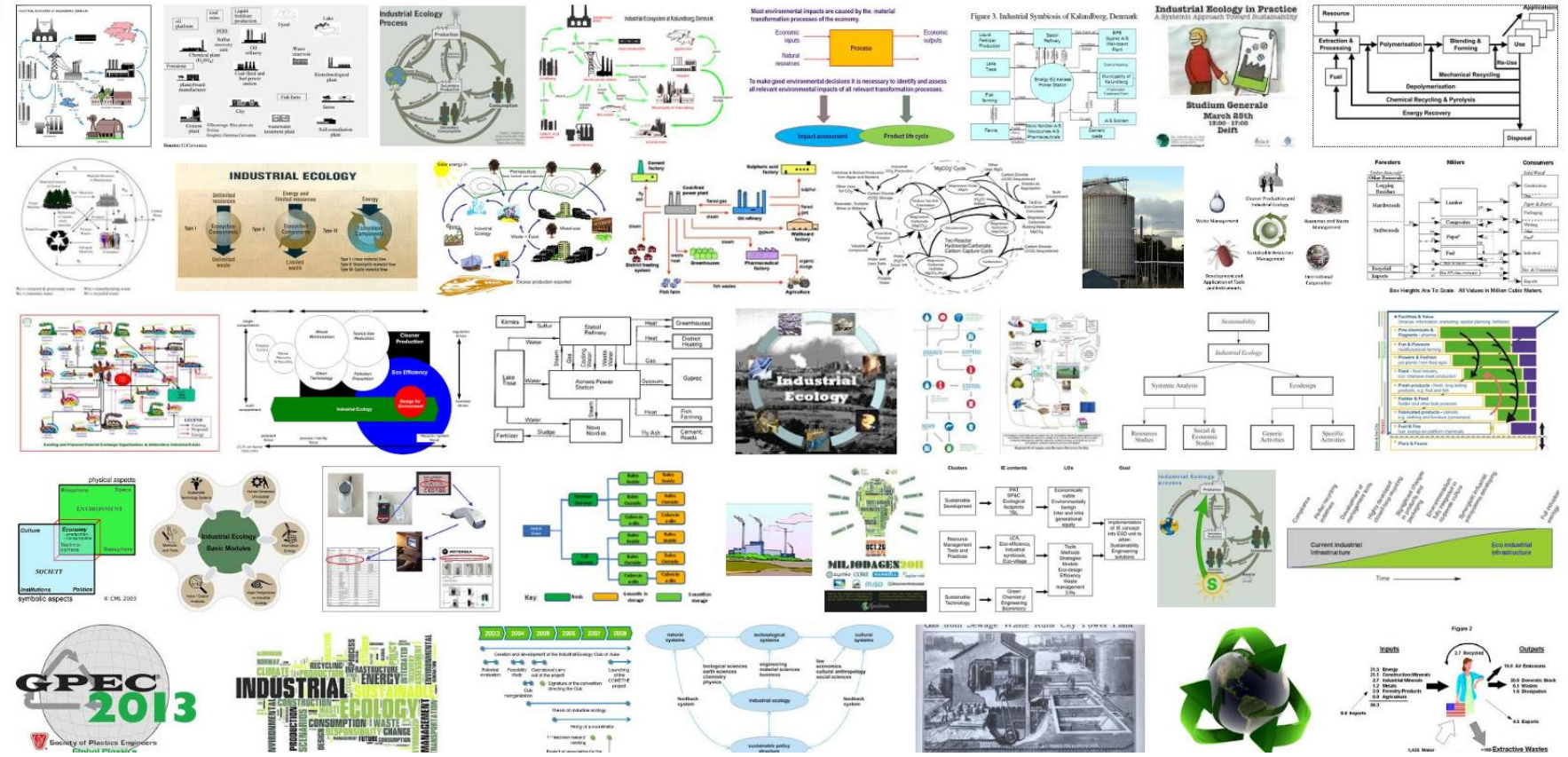


A bit of history of Industrial Ecology

- In 1865 Karl Marx is the first to apply the term *Metabolism* to human society and labor
- In 1989, Robert Ayres developed concept of *Industrial Metabolism*:
  Industry *metabolizes* materials and energy and transforms them into useful products, wastes and emissions
- In 1989, Robert Frosch and Nicholas Gallopoulos developed the concept of *Industrial Ecosystems:*
  The notion creates an analogy between biological and industrial food webs. In an *industrial ecosystem*, waste product by one company should be used as a resource for another.
- In 1991, the National Academy of Science hosts Symposium on *Industrial Ecology*
- In 1994, the National Academy of Engineering publishes
  The Greening of Industrial Ecosystems (Eds. Braden Allenby & Deanna Richards)
- 1997, publication of the first issue of the *International Journal of Industrial Ecology*
- 2001, foundation of the *International Society of Industrial Ecology* (http://www.is4ie.org)
- Both Metaphors were also independently developed and used in other countries, like Switzerland (Baccini & Brunner, 1991), in Belgium (Billen et al., 1983) and in Japan (Watanabe, 1973)

Industrial Ecology

If you search Industrial Ecology (IE) in Google…



Connection, flows (arrows, mass quantity), networks, supply chain ….

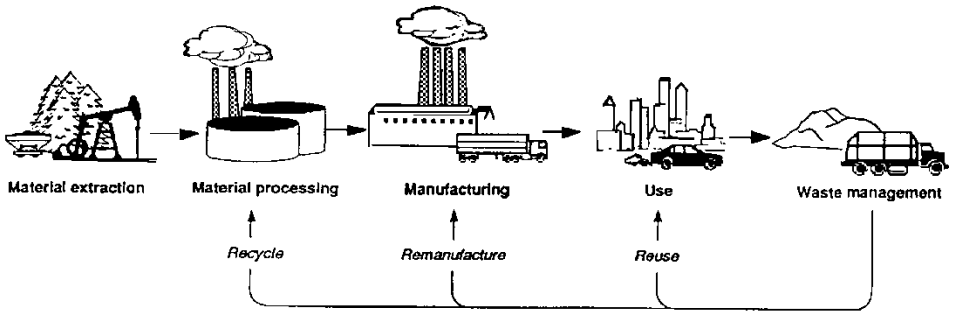
Tools, techniques and approaches

- Life Cycle Assessment
- Life cycle costing
- Material, Energy and Waste Flow Analysis
- Dematerialisation and Decarbonisation
- Carbon and Water Footprint, Indicators
- Eco-Industrial Parks ('Industrial Symbiosis')
- Design for Environment, Recycling, Resource management
- Agent Based Modelling, System dynamics
- Design for X ……

Research Experience

1) Life Cycle Assessment (LCA) of Products

: technique and tool for analyzing the environmental performance over the entire life cycle of a product, service or system.



Q) Which one the lowest environmental impact ?





Research Experience

- Case study: Pulp, Paper, Paper cup and Packaging Products





- Life Cycle Assessment in forklift manufacturing processes
- By applying new high solid painting system, 20% total environmental impacts was reduced.

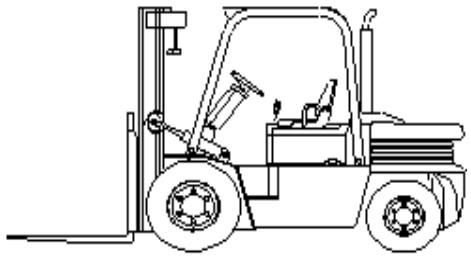
International Journal of Production Research
Vol. 48, No. 10, 15 May 2010, 3061–3078

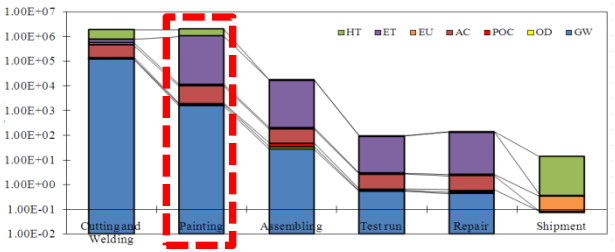
Taylor & Francis
Taylor & Francis Group

Sustainable manufacturing: a case study of the forklift painting process

Junbeum Kim[a]*, Kwangho Park[b], Yongwoo Hwang[b] and Ildo Park[c]

[a]*Center for Earth Systems Engineering and Management, Department of Civil, Environmental and Sustainable Engineering, Arizona State University, PO Box 875306, Tempe, AZ 85287-5306, USA;* [b]*Department of Environmental Engineering, Inha University, 253, Namgu, Inchon, South Korea;* [c]*Production Technology Team, Daewoo Heavy Industries Ltd., Incheon, South Korea*





Research Experience

2) Life Cycle GHG emission for Infrastructure System

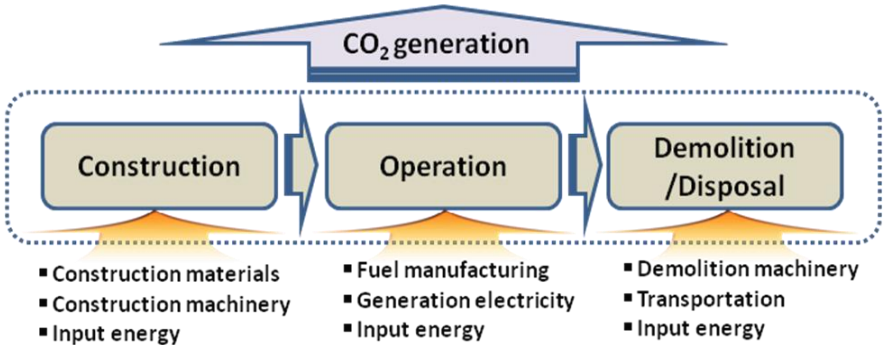


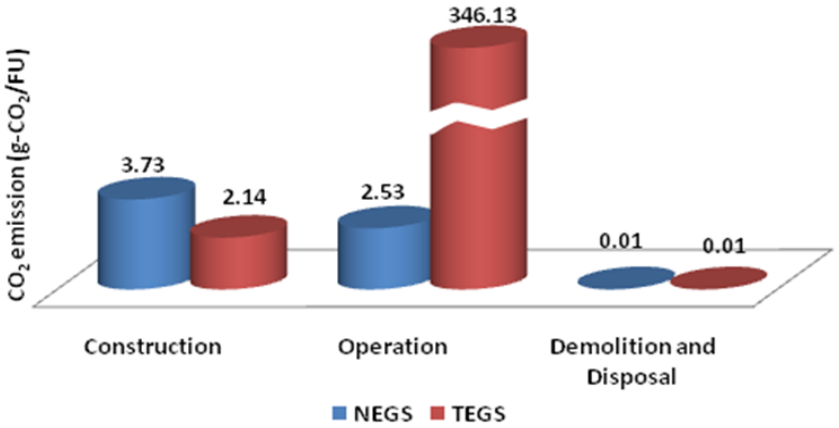
VS.



Nuclear Electricity Generation System

LNG Thermal Electricity Generation System

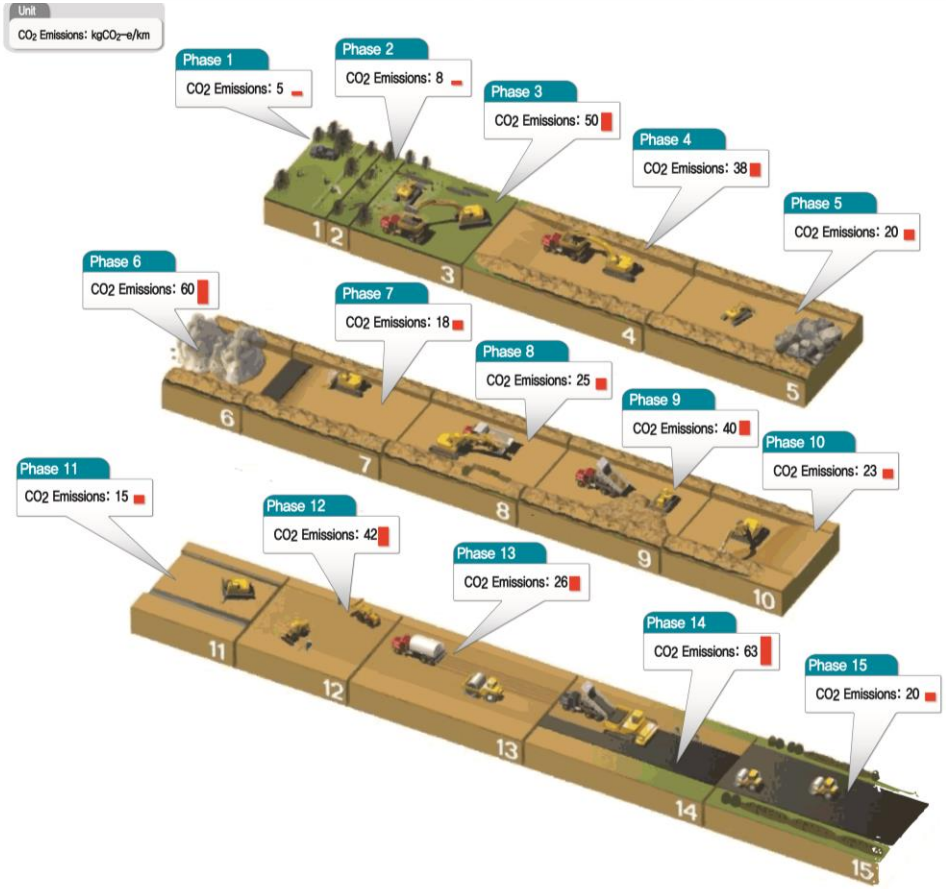




Research Experience

2) Life Cycle GHG emission for Infrastructure System

: Life Cycle CO2 Emissions in Road Construction and Rehabilitation



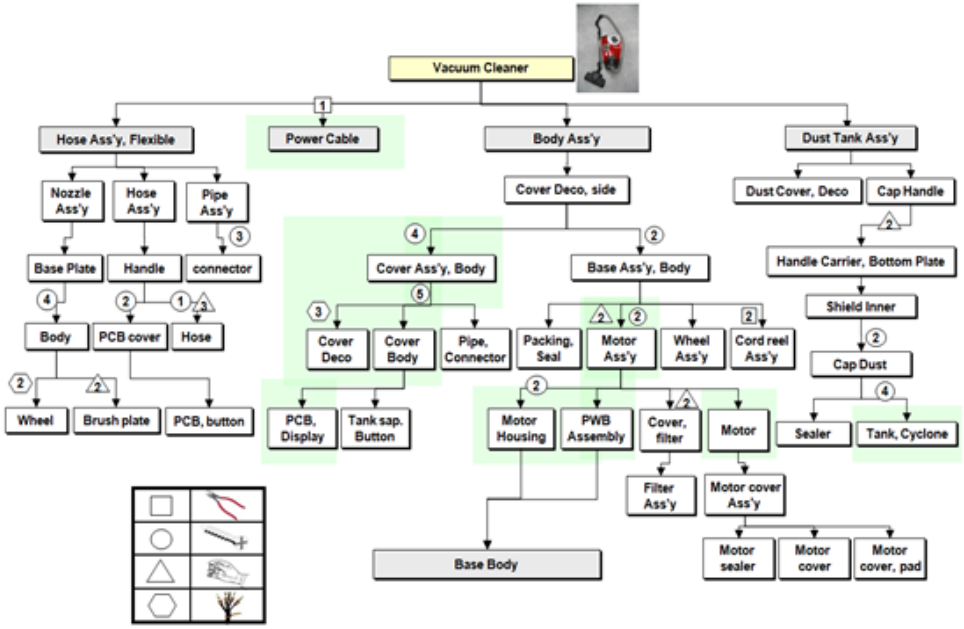




Research Experience

3) Design for Environment (DfE) for Electronics Products (with Samsung and LG)

- A general concept that refers to a variety of design approaches that attempt to reduce the overall environmental impact and cost of a product, process and service.
- Design for disassembly and recycling (TV, DVD, computer, cell phone, etc.)
- Disassembly parts tree diagram and materials information data development

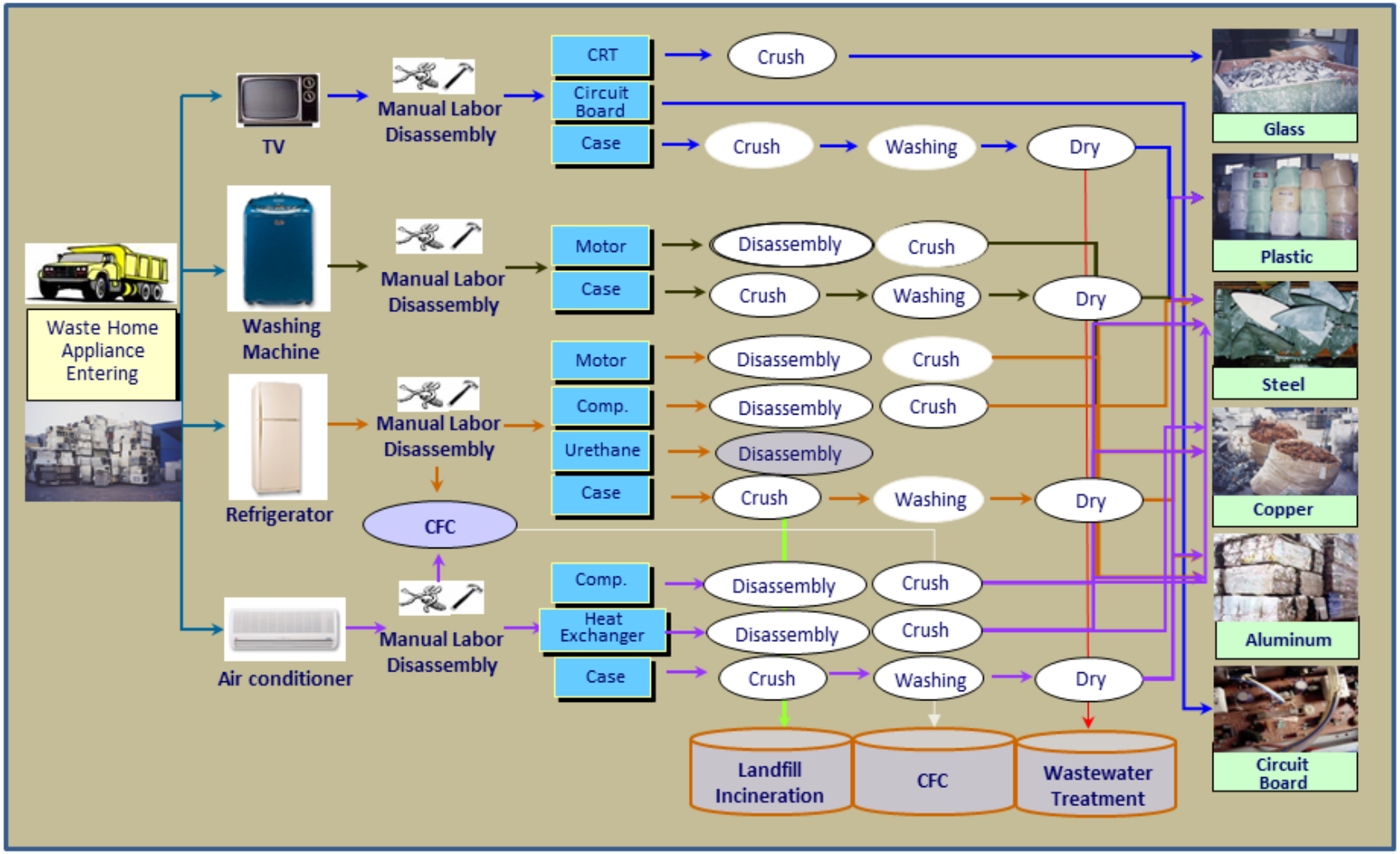


Item		Result
Recycling rate	Product A	59.6 %
	Product B	70.3 %
Recovery rate	Product A	89.6 %
	Product B	96.8 %
Disassembly time	Product A	212 (sec.)
	Product B	191 (sec.)
Disassembly cost	Product A	-1.48 $
	Product B	-1.33 $
Recycling cost	Product A	-1.37 $
	Product B	-1.20 $

Junbeum Kim and Braden R. Allenby, Improvement Plan of Recycling of the Electronic & Electrical Equipment with Considering of Economics: Case study of Vacuum Cleaner, "2006 IEEE International Symposium on Electronics and the Environment" San Francisco, CA. pp 336-339.

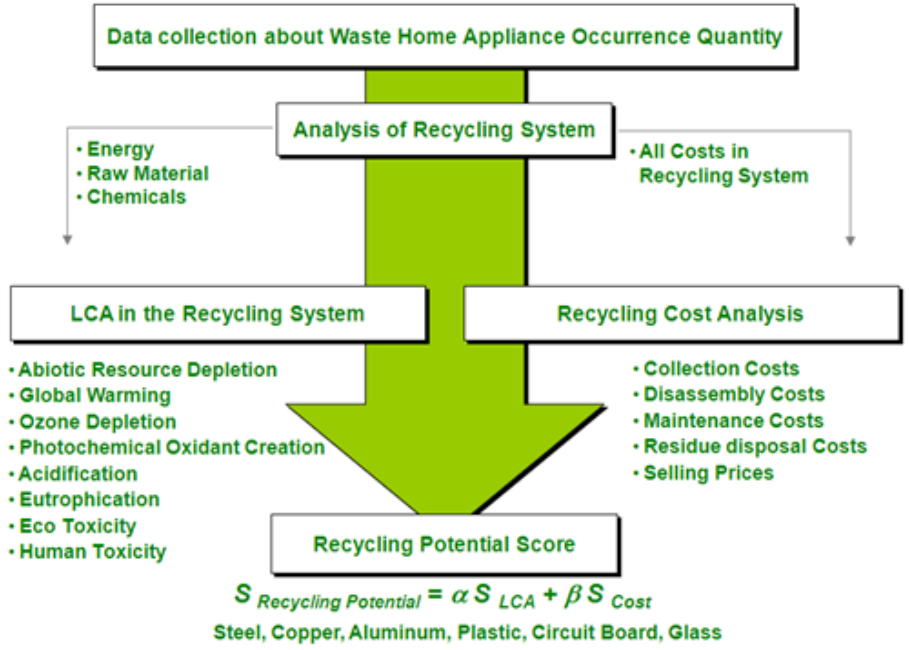
Research Experience

5) Economic and Environmental Assessment for E-waste Recycling System

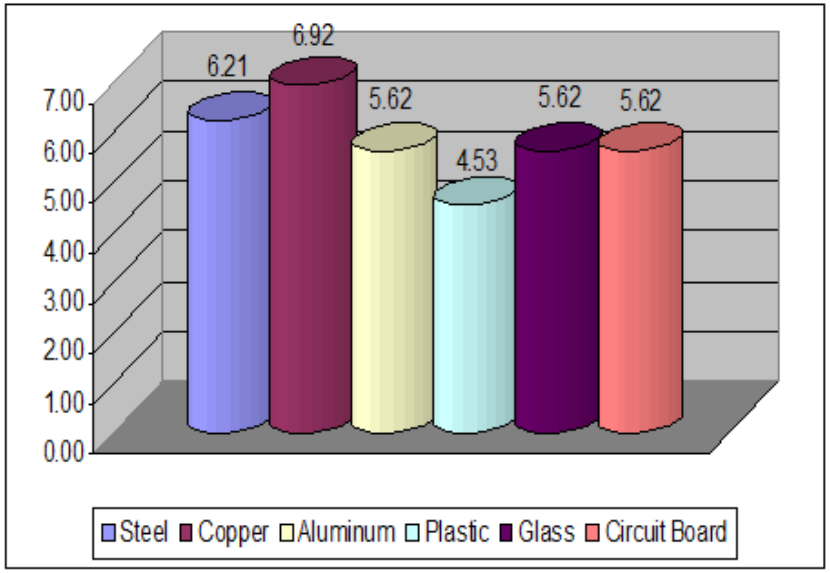


Research Experience

5) Economic and Environmental Assessment for E-waste Recycling System



Recycling Potential Score of Each Materials



Journal of Cleaner Production 17 (2009) 1264–1271

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro



An assessment of the recycling potential of materials based on environmental and economic factors; case study in South Korea

Junbeum Kim [a,*], Yongwoo Hwang [b], Kwangho Park [c]

[a] Department of Civil and Environmental Engineering, Arizona State University, PO BOX 875306 Tempe, AZ 85287-5306, USA
[b] Department of Environmental Engineering, Inha University, 253, Namgu, Incheon, South Korea
[c] CSIRO Manufacturing & Infrastructure Technology, PO Box 56, Highett, Vic 3190, Australia

Research Experience

6) E-Waste Collection and Recycling System Management in the U.S.

Environmental Research & Education Foundation

EREF

Lighting a path to sustainable waste management practices

Junbeum Kim (EREF Scholar 2007-2009), Research fund: $36,000

: Sustainable System Design for Collection and Recycling of E-waste in the United States



Resources, Conservation and Recycling 52 (2008) 955–964

Exploring e-waste management systems in the United States

Ramzy Kahhat[a,*], Junbeum Kim[a], Ming Xu[a], Braden Allenby[a], Eric Williams[a,b], Peng Zhang[a]

[a] Department of Civil and Environmental Engineering, Arizona State University, Tempe, AZ 85287, USA
[b] School of Sustainability, Arizona State University, Tempe, AZ 85287, USA

ENVIRONMENTAL Science & Technology

Environmental, Social, and Economic Implications of Global Reuse and Recycling of Personal Computers

ERIC WILLIAMS,*,†,‡ RAMZY KAHHAT,†
BRADEN ALLENBY,† EDWARD KAVAZANJIAN,†
JUNBEUM KIM,† AND MING XU†

Department of Civil and Environmental Engineering and School of Sustainability, Arizona State University, Tempe, Arizona 85287

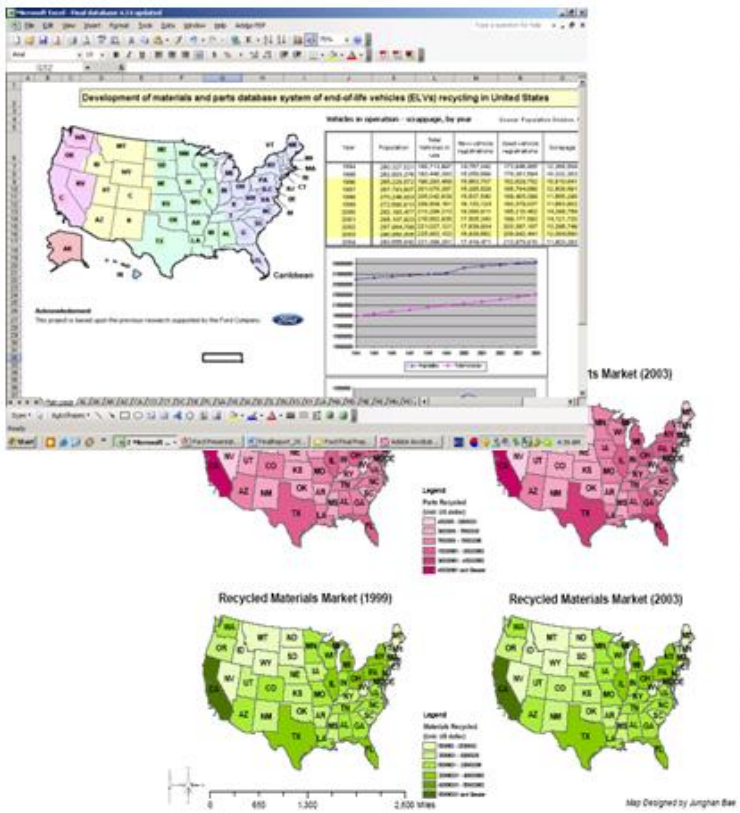
Research Experience

7) Recyclability and recoverability of materials and parts from End-of-life Vehicles

PI, Ford Motor Company Graduate Research Grant (2005)

8) Development of Materials and Parts Database of ELVs Recycling System in the U.S.

CO-PI, Ford Motor Company Graduate Research Grant (2006)











Material Flow Analysis

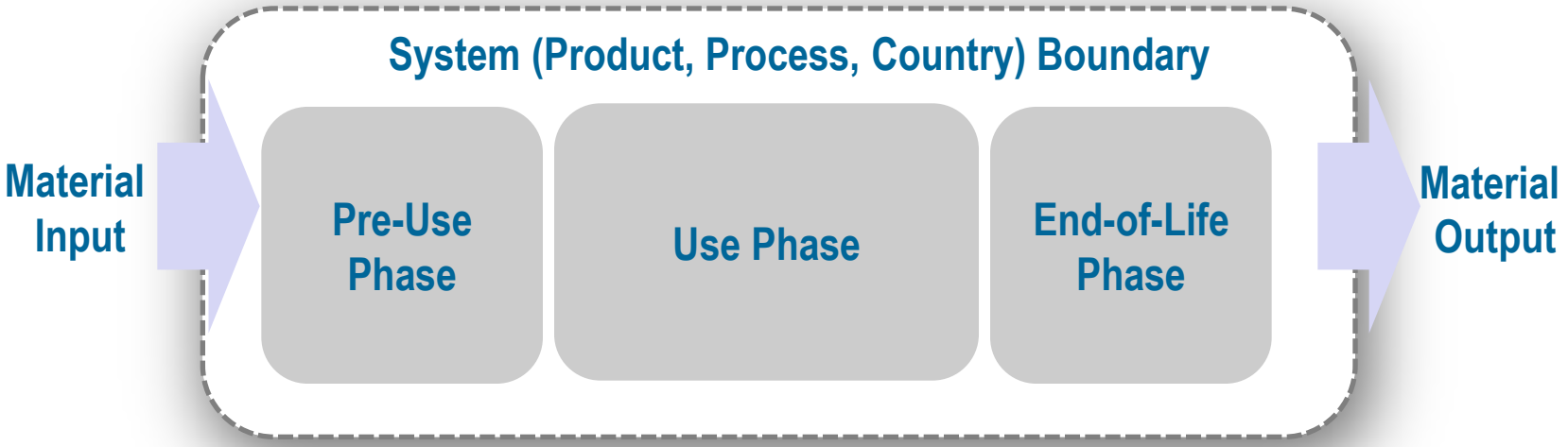
Many countries are working for “Sustainable System and Society”

: Sound Material Cycle Society (Japan), Circular Economy , Resource-Circulating Society, etc.

: Industrial Ecology, Sustainable Engineering, Material Flow Analysis (MFA), Design for Sustainability, Life Cycle Assessment (LCA) etc.

Material Flow Analysis (MFA)

: a systematic assessment of the flows and stocks of materials within a temporal and spatial system (Paul et al., 2004).



Material Flow Analysis

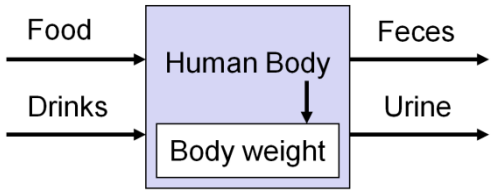
First study of the metabolism of the human body



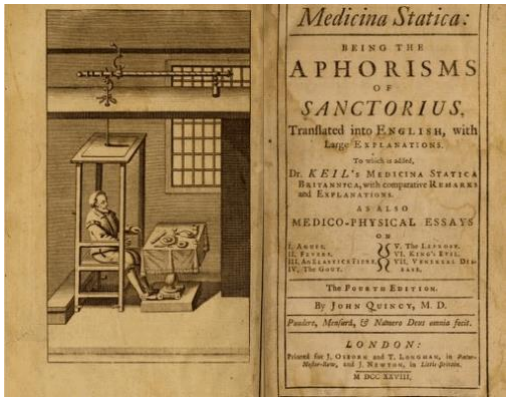
Santorio Santorio
(1561-1636)
Physician from
Padua, Italia



Santorio's initial experimental setup to analyze the material flows in a human body

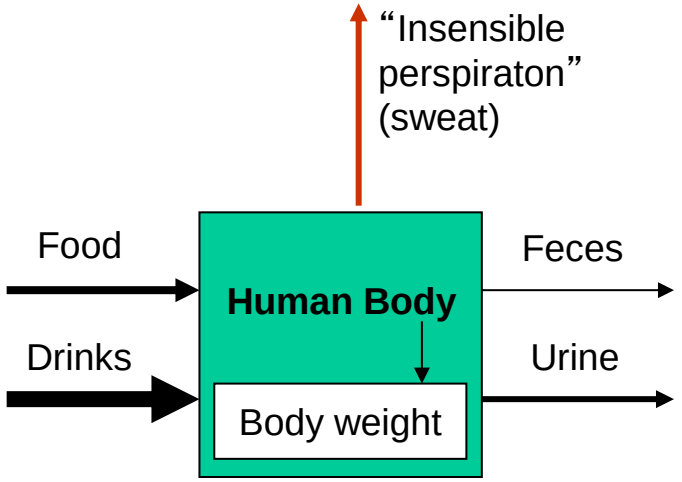






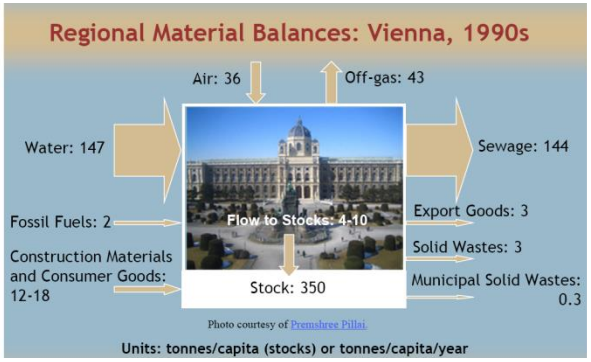


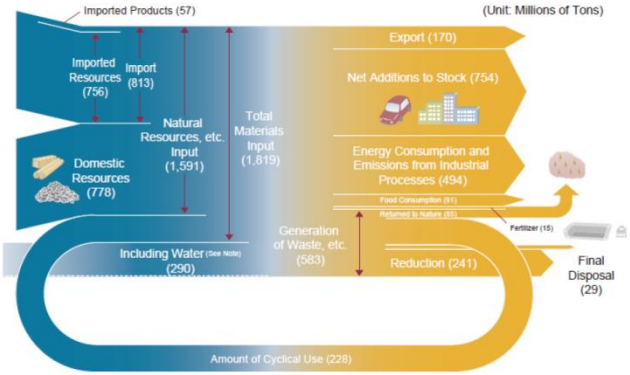
- Measurement of the "insensible perspiration" at night

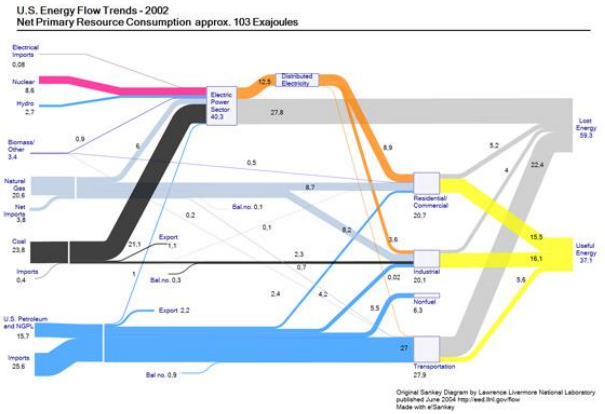


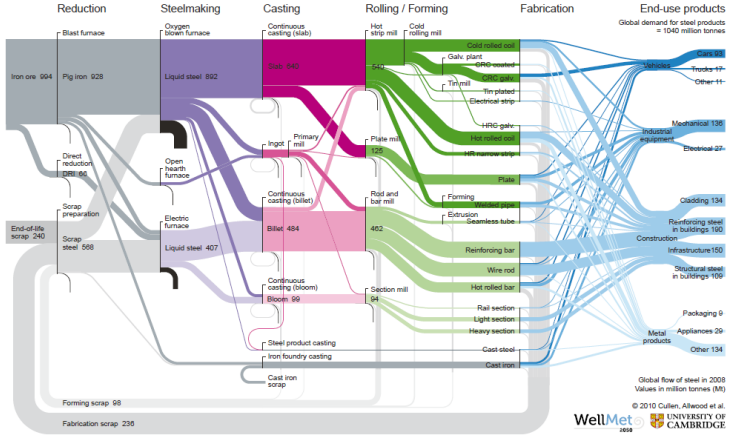
MFA and sustainable sustainable resource management

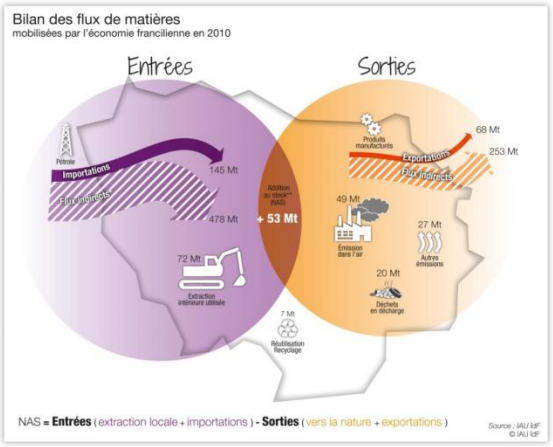
Application of Material flow analysis (MFA)
: steel, copper, Al, cement, rare materials, waste, water, energy, food etc.

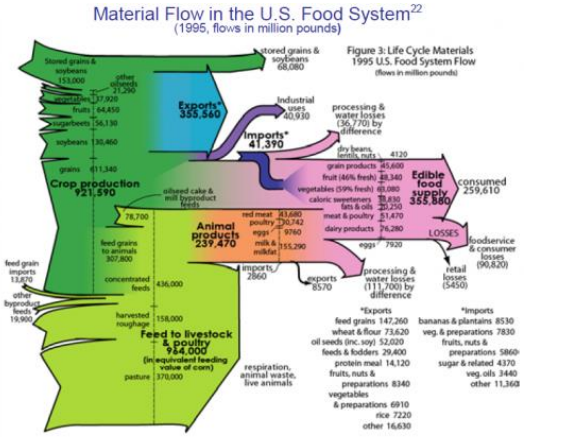






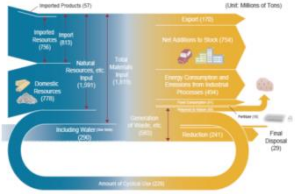
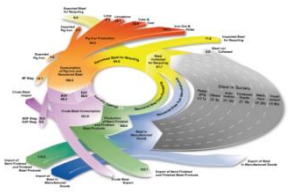




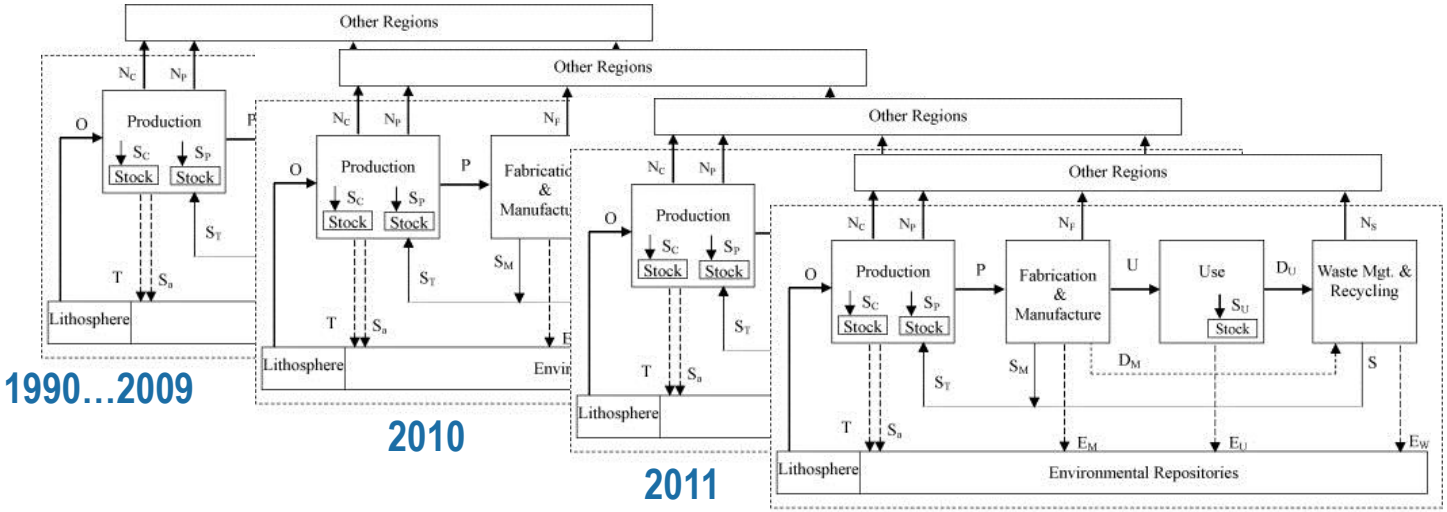


MFA and Sustainable Resource Management

Dynamic Material Flow Analysis of Steel and Aluminum in Europe
(3 years project, 2014-2017)


Dynamic Material Flow Analysis (DMFA)
: Lifetime distribution to the static flow of a material to analyze and forecast its flow over time (Elshkaki, 2007)

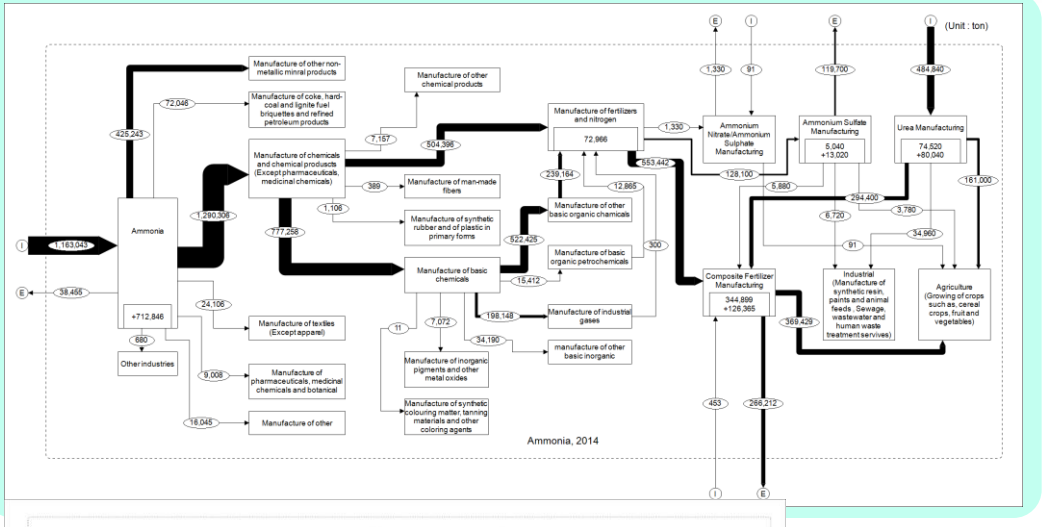


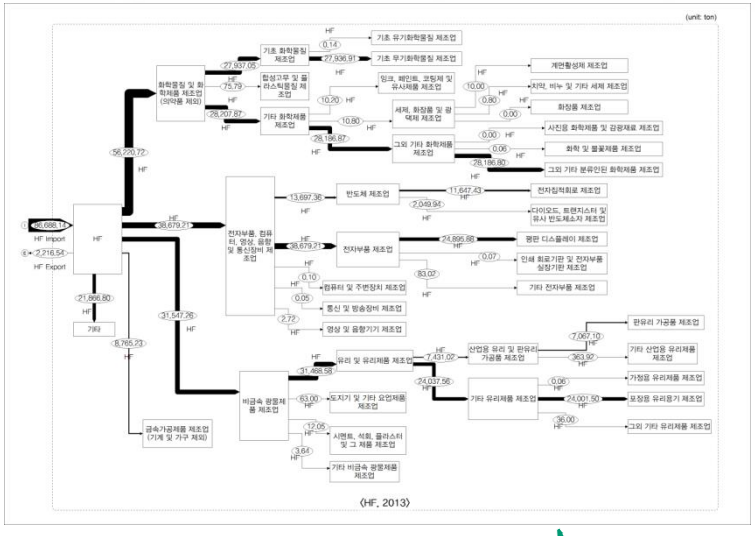
Chemical Material flow analysis (CMFA)

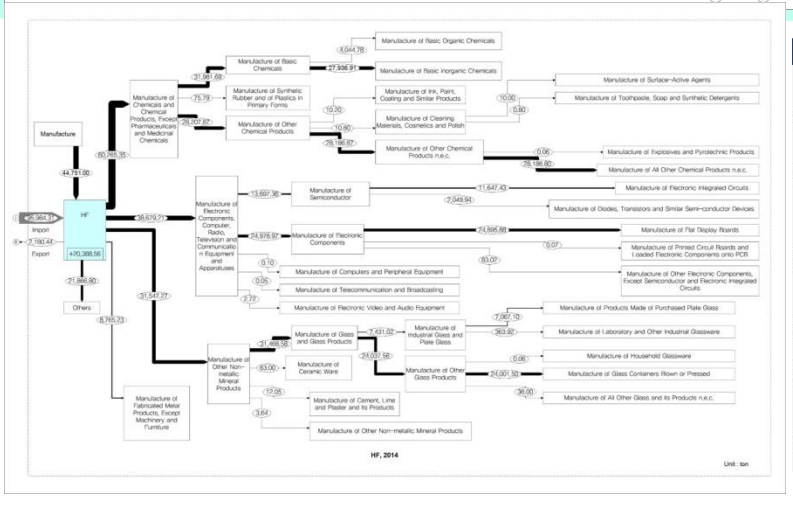
Current research on CEMFA (Master students in Inha University)

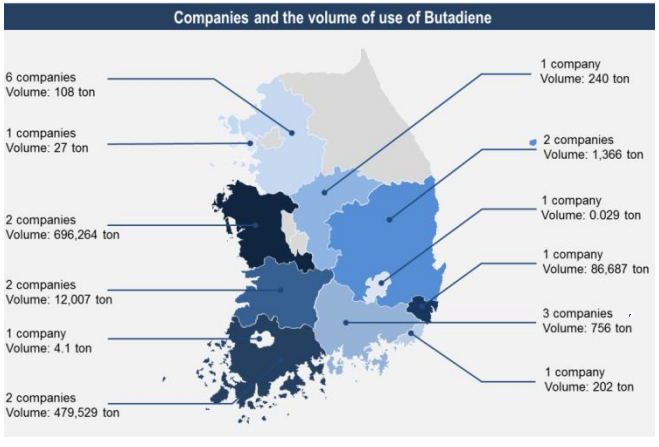
Chemicals: Butadiene, HF Hydrogen fluoride, Ammonia

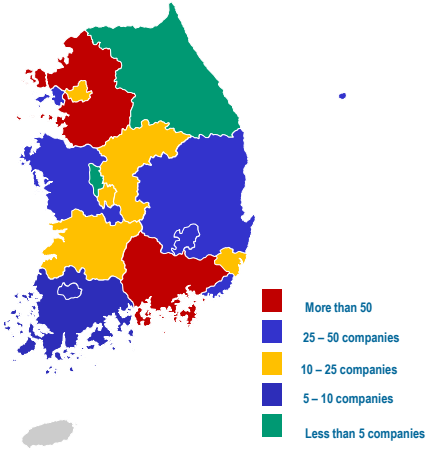
Application of Material flow analysis (MFA) => Chemical flow analysis











Recycling of renewable energy system

- **RECYCLED: Recyclage de lampes à LED (AAP Régionaux project)**

  2016 - 2018, € 1.1 M

- **Critical and precious materials consumption and requirement in renewable energy system**

  2015 – 2017, € 300,000

- **Recycling and resource recovery of renewable energy system**









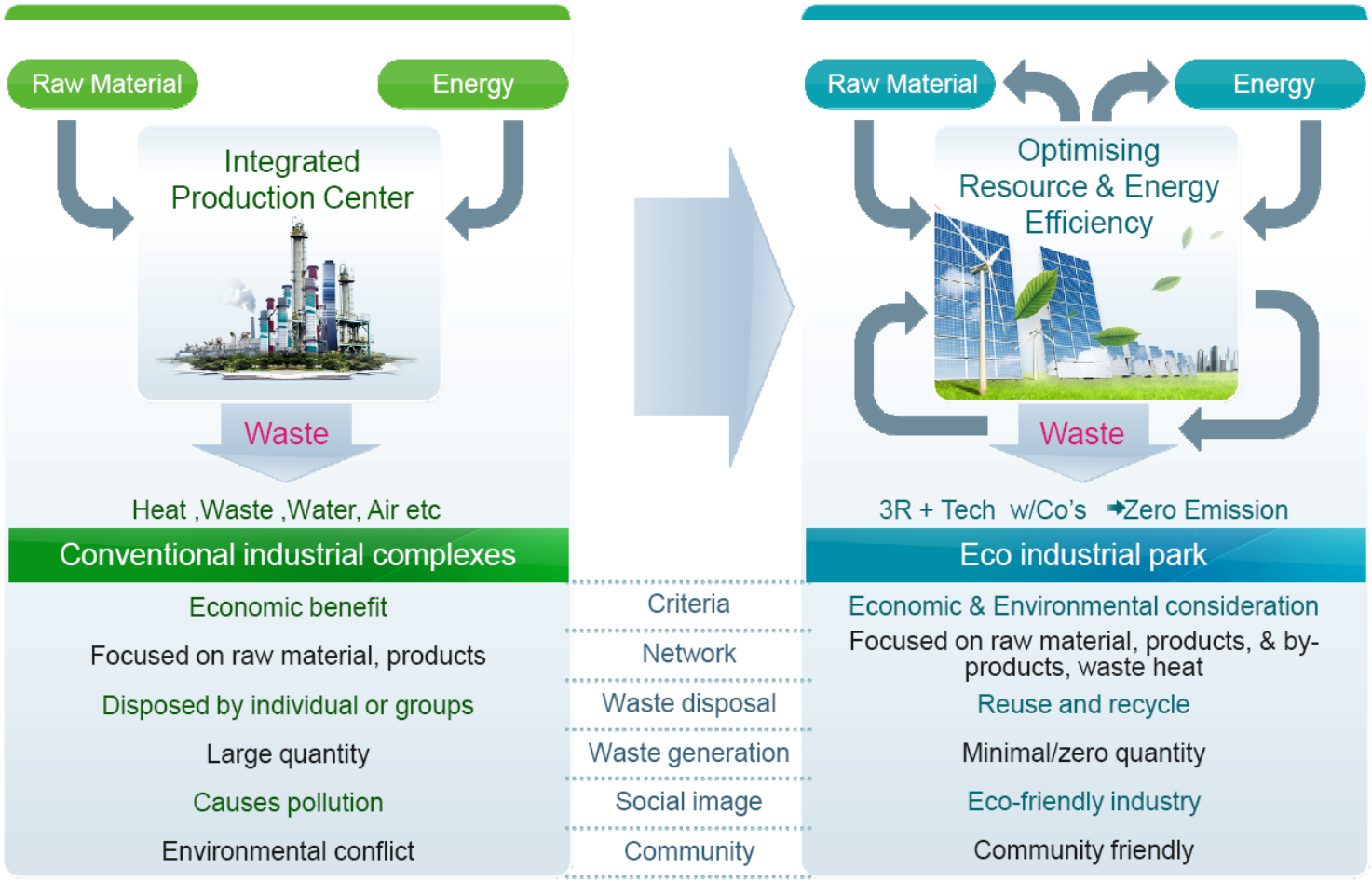




Eco-industrial Park,
Networking of Industrial Waste Resources

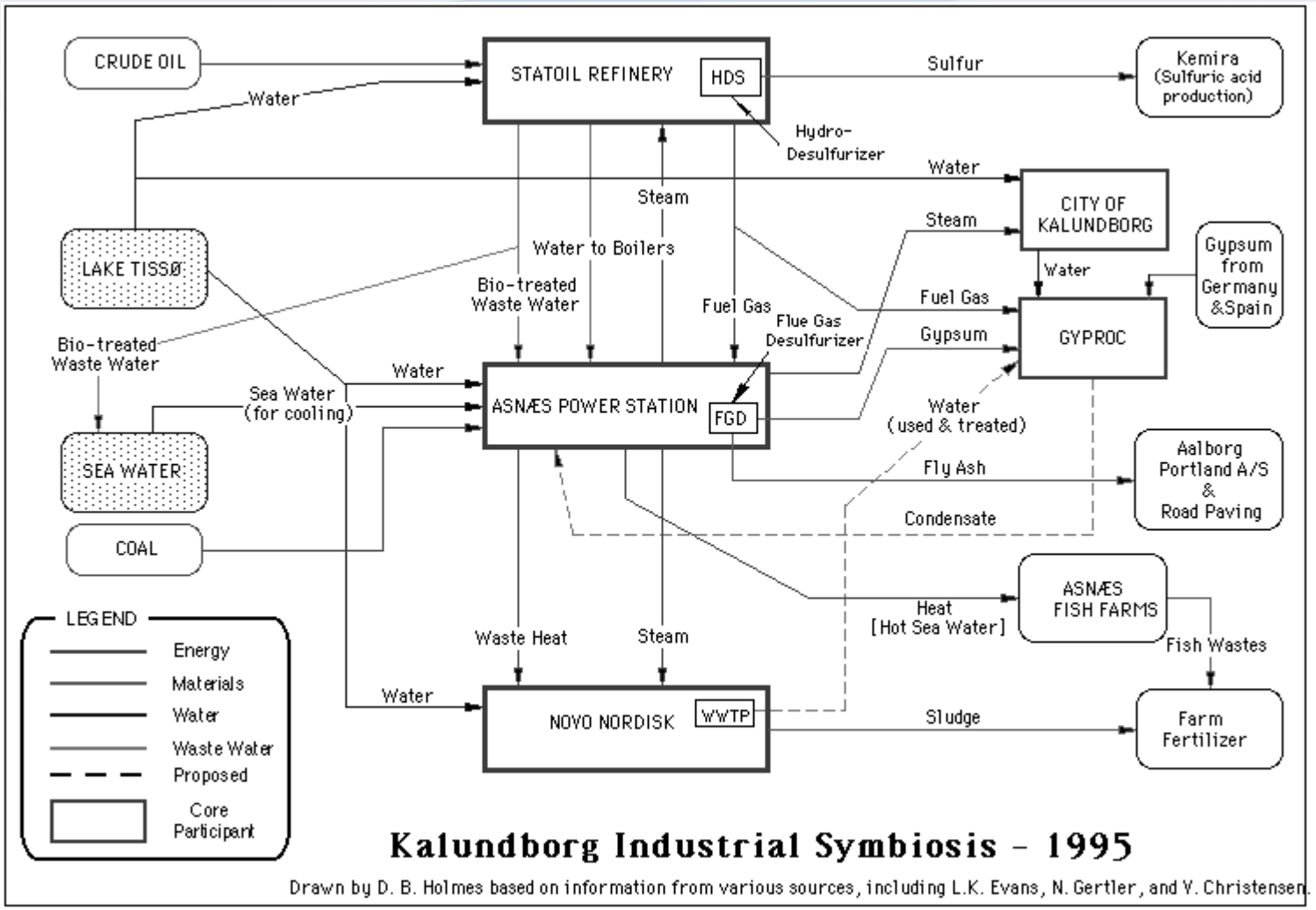
What is Eco-industrial Park (EIP)?

What is EIP?



Source: HS Park, 2015

Kalundborg Eco-industrial Park



http://www.indigodev.com/Kal.html

Other cases

MK 매일경제 MBN | 뉴스 | 오피니언 | 프리미엄 | 연예 | 스포츠 | 증권 | 부동산 | 교육 | 비즈& | 구독신청 | 로그인 | 회원가입

뉴스홈 전체기사 경제 기업 사회 국제 부동산 증권 정치 IT·과학 문화 기획·연재 Special Edition 인기뉴스 | 속보 | 나흘 동안 9자례 흔들...심상찮은 한반도..



소각장 스팀으로 옆공장 기계 돌려

입력 : 2009.04.13 17:25:58

◆녹색성장 산업단지도 뛴다 / ② 에너지 네트워크 시대◆



△울산 성암소각장은 생활쓰레기를 태우고 나온 스팀을 스팀헤드 장치(사진 왼쪽)에서 고압 처리한 뒤 이를 스팀 파이프를 통해 효성 용연 제2공장에 보내고 있다.

울산시 남구 성암동에 자리 잡은 성암소각장. 울산시가 보유하고 있는 유일한 도시폐기물 소각시설인 이곳에서는 24시간 쓰레기 소각작업이 쉴 새 없이 진행되고 있다.

이 소각장의 가장 큰 입지적 특성은 울산 최대 국가산업단지인 울산·미포국가산업단지의 용연지구 한가운데 자리 잡고 있다는 것. 쓰레기를 태우고 남은 뜨거운 수증기는 스팀헤드라고 불리는 장치를 거쳐 고온(섭씨 203도)·고압(16kg/㎠) 스팀으로 바뀐 뒤 근처 700m 옆 효성 용연 제2공장으로 흘러간다.

울산최초, 최고의 조간신문 **울산매일**

검색 할 기사를 입력하세요. | 인사 | 선암 | 1366

뉴스 | 오피니언 | 포토 | 기획 | 영상 | 신문보기

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폐자원 활용으로 자원순환 네트워크 구축

고유가·경제침체 등'폐열 재활용 사업'주목성암소각장'스팀'기업에 공급 ... 78억 경제효과

12면 기사보기 신문보기 JPG 특별취재팀=배준호·김영수·이창균 기자 승인 2008.11.20 00:00 댓글 0

[사진]◇성암소각장 스팀 공급은 소각장에서 발생하는 폐스팀을 인근 효성 용연 제2공장에 공급하는 것으로, 지난 6월에 준공했다.

[사진]◇스팀생산은 시간당 45톤의 스팀을 발전용으로 23톤, 소각시설 설비 운영 및 음식물 자원화 시설운영에 11톤, 고압복수기에 11톤을 사용한다.

<9> 자원재활용, 경제극복 지름길③성암소각장스팀공급사업

공장을 돌리면서 나오는 열과 가스, 유기물과 같은 폐자원과 부산물을 잘만 활용하면 기업의 경쟁력 강화와 지자체의 경영수익 확대에 있어 성과를거둘 수 있다.

그동안 생활폐기물의 소각과정에서발생되는 폐열은 활용가치가 없는'애물단지'였지만 최근 고유가시대와 경기침체가 지속되면서 이를 재활용한 사업이 주목받고 있다.

건설 | 부동산 | 경매

주천 경매물건(3월 6일)



남구 삼산동 한화꿈에그린아파트 127.469㎡ 사건번호 : 2016타경 68..

많이본 기사

오늘지면 | 어제지면 | 주간 Hot | 월간 Hot

1 90년대 풍미한 '한국계' 미국 아이돌 토미
2 [민주당 토론회] 최성 '안희정 저격수로
3 배우 민욱의 추억..."80년대와의 이별 슬
4 갤럭시S8 빠진 MWC...스마트폰 '준추 중
5 [영상] 표창원 "박영수·이정미 손석희 협

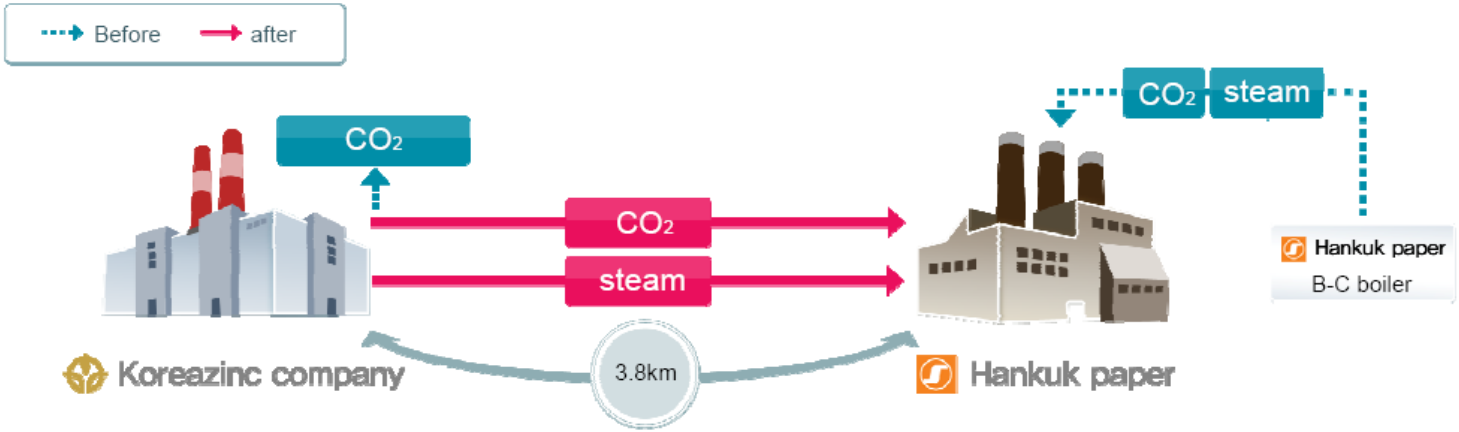
연예 Hot | 스포츠 Hot

[중국 금한령] "'도깨비' 이동욱 100억 벌

Excellent Case

KICOX

CO_2 and steam network between Paper mill and Zinc smelter



Input(Initial Investment)

- Facility investment : steam and CO_2 pipe (total 3,872m) the cost of equipment : $22.0 mil.

Output(Income : Business scale : steam 50~80 ton/hr, CO_2 50 ton/hr supply)

- Reduction of GHG emission : CO_2 63,643 ton/yr (about $ 0.7 mil./yr)
- Cost Cut from raw material & waste reduction : $6.6 mil./yr

Other cases

Excellent Case

KICOX

Organic Waste-to-Energy Network (PPP project)

ULSAN METROPOLITAN CITY

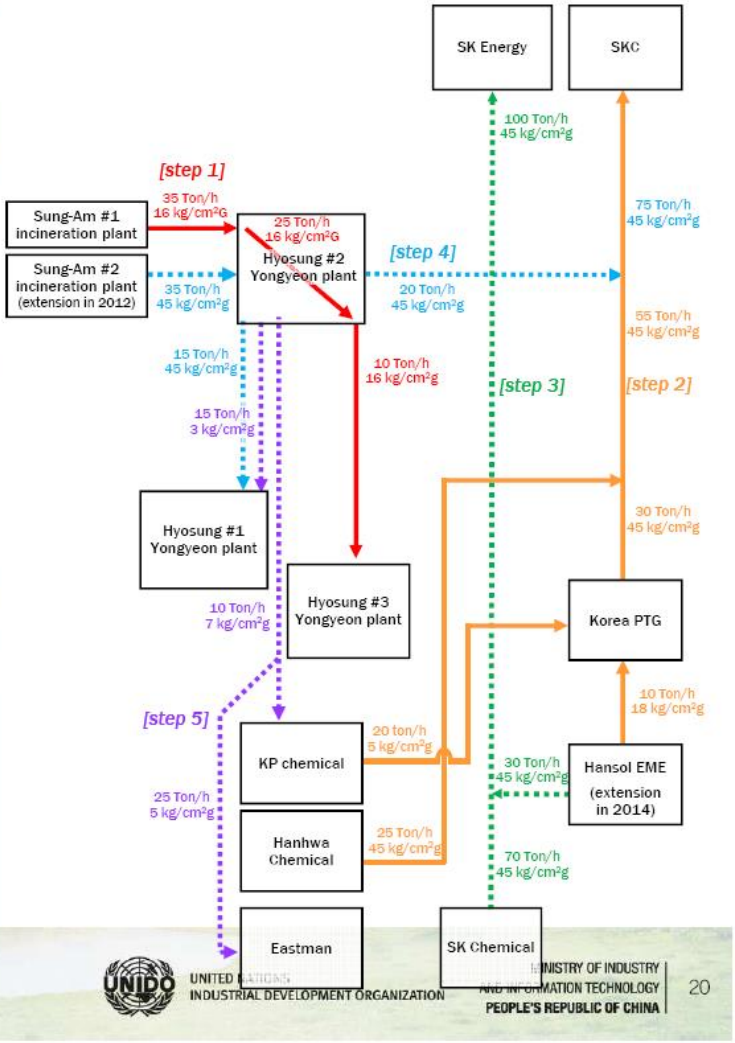


- Economical Result
  : $ 2 mil./yr profit because of 2,703 toe/yr Energy sustitution.

- Preparing for the Anti-Marine dumping Law effective from 2013.

Other cases


SK Energy
SKC
SK Energy
FCC Plant
Hyosung #2
Yongyeon Plant
Sung-Am #1
Incineration Plant
Hyosung #1
Yongyeon Plant
Sung-Am #2
Incineration Plant
Hyosung #3
Yongyeon Plant
SK Energy
Korea
PTG
KP Chemical
Hanwha Chemical
Hansol Chemical
Eastman
SK Chemical


SK Energy
SKC
100 Ton/h
45 kg/cm²g
[step 1]
Sung-Am #1
incineration plant
35 Ton/h
16 kg/cm²G
25 Ton/h
16 kg/cm²G
Hyosung #2
Yongyeon plant
[step 4]
75 Ton/h
45 kg/cm²g
Sung-Am #2
incineration plant
(extension in 2012)
35 Ton/h
45 kg/cm²g
20 Ton/h
45 kg/cm²g
55 Ton/h
45 kg/cm²g
15 Ton/h
45 kg/cm²g
10 Ton/h
16 kg/cm²g
[step 3]
[step 2]
15 Ton/h
3 kg/cm²g
Hyosung #1
Yongyeon plant
30 Ton/h
45 kg/cm²g
Hyosung #3
Yongyeon plant
10 Ton/h
7 kg/cm²g
Korea PTG
10 Ton/h
18 kg/cm²g
[step 5]
KP chemical
20 ton/h
5 kg/cm²g
Hansol EME
(extension
in 2014)
30 Ton/h
45 kg/cm²g
25 Ton/h
5 kg/cm²g
Hanhwa
Chemical
25 Ton/h
45 kg/cm²g
70 Ton/h
45 kg/cm²g
Eastman
SK Chemical

Current international support and collaborations

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

UNIDO



ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
OECD

NISP™

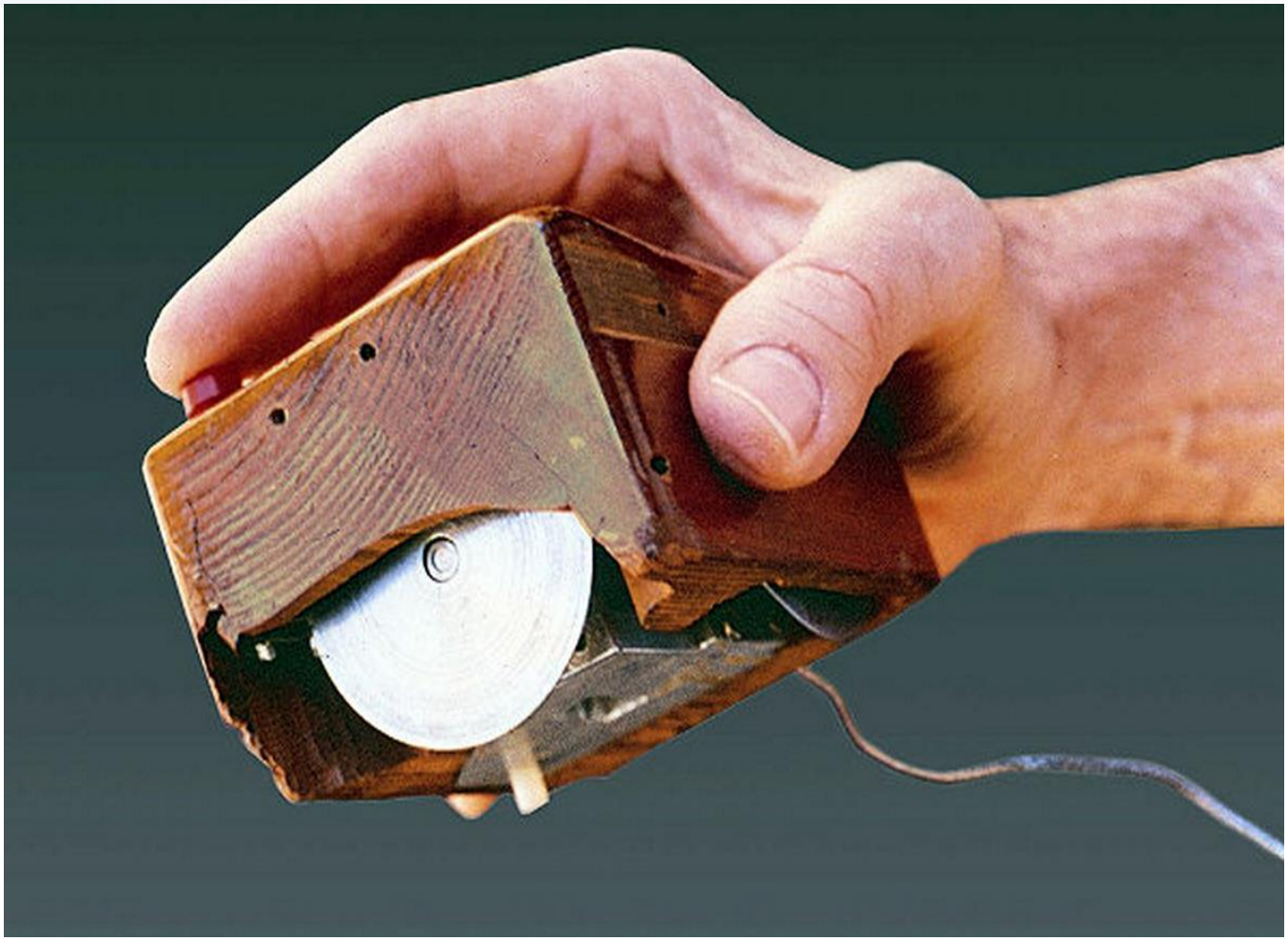
International Society for Industrial Ecology

IFC International Finance Corporation
World Bank Group

One issue in developing countries and appropriate technology

One question!

Can you guess? What is this?



This is the first computer mouse





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NETAPP DÉSIGNÉ LEADER SUR LE FLASH DANS LE MAGIC QUADRANT GARTNER 2016
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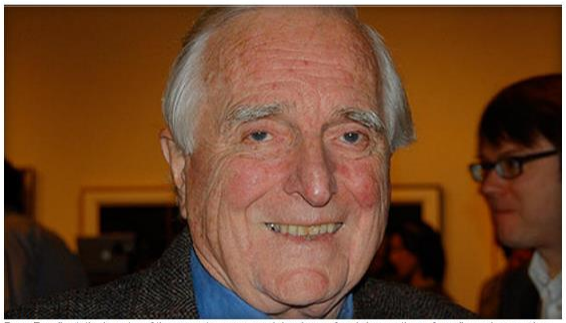
AP / *July 4, 2013, 9:25 AM*

Inventor of computer mouse dies at age of 88



Doug Engelbart, the inventor of the computer mouse and developer of early incarnations of email, word processing programs and the Internet. / **FLICKR/ALEX HANDY**

Comment / Share / Tweet / Stumble / Email

Doug Engelbart, the inventor of the computer mouse and developer of early incarnations of email, word processing programs and the Internet, has died at the age of 88.



The mouse Doug Engelbart and Bill English created in 1968. / **STANFORD RESEARCH**

The Computer History Museum, where Engelbart had been a fellow since 2005, says he died early Wednesday. The museum in Mountain View, Calif., was notified of the death in an email from his daughter, Christina. The cause of death wasn't immediately known.

Engelbart's biggest breakthrough was the computer mouse, which he developed in the

NETAPP DÉSIGNÉ LEADER SUR LE FLASH DANS LE MAGIC QUADRANT GARTNER 2016
LIRE LE RAPPORT
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05 Donald Trump reacts to Hillary Clinton's pneumonia diagnosis 53921 *views*

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He invented the first computer mouse in 1968.
It was a wooden shell covering two metal wheels

Doug Engelbart's biggest breakthrough was the computer mouse
Read more: http://www.dailymail.co.uk/news/article-2355116/Inventor-mouse-Doug-Engelbart-dies-aged-88.html#ixzz3bqSXa26a

The first computer mouse to current mouse

The first computer mouse (1968)





Wired computer mouse







1990’ computer mouse





Wireless computer mouse

The first electronic television

The first electronic television (1927)



Philo Tayor Farnsworth demonstrates his new combination radio and television receiving set at the Farnsworth Television Laboratories, Philadelphia, PA, July 1935.

RCA 630-TS, the first mass-produced television set, which sold in 1946–1947



1950' Electronic television (1)



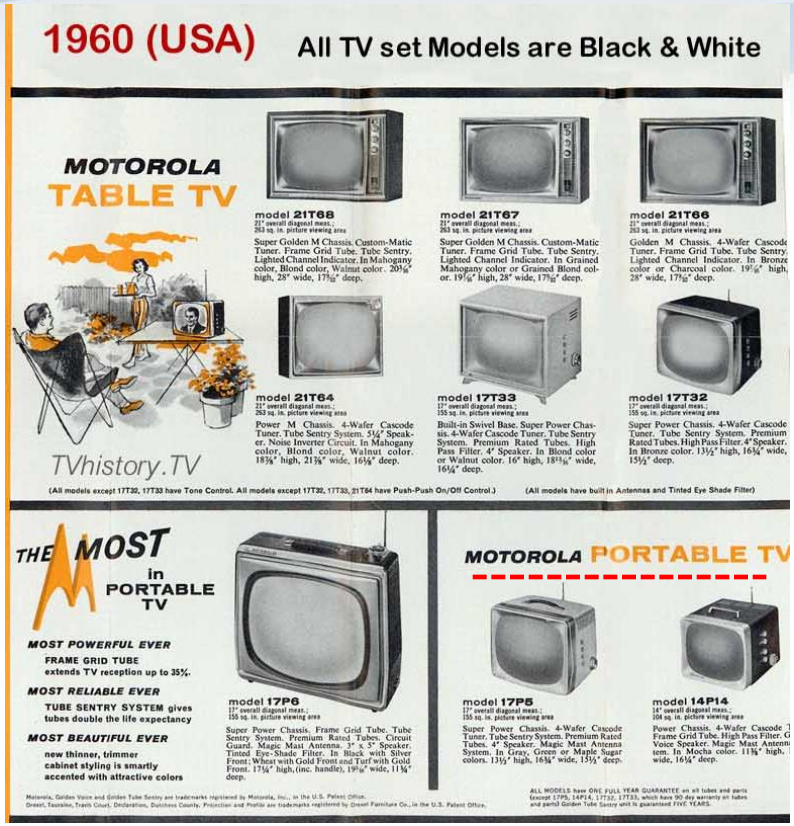
1950' Electronic television (2)



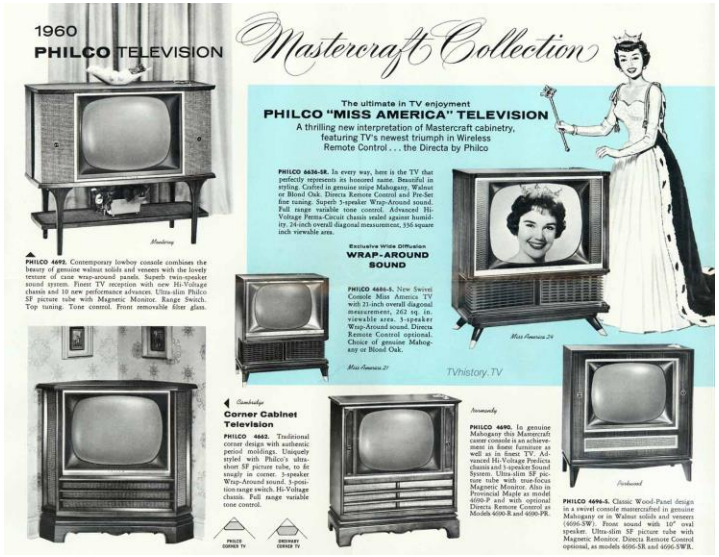


Source: http://www.vintageadbrowser.com/electronics-ads-1950s/72

1960' Electronic television







http://www.tvhistory.tv/1962-Magnavox-Brochure-3.JPG

1990 - 2000’ Electronic television



BEOVISION LX5500 28”
Total weight: 42.7 kg







http://www.beoworld.co.uk/beovisionlx5500_4500.htm

Henrik Wenzel, Environmental Assessment of Products

Various TV technologies like Plasma and LCD are in experimental stages!!

Current Electronic television





4.9mm thin Sony XBR 4K TVs





Hi-technology and E-waste

E-waste is a popular, informal name for electronic products nearing the end of their "useful life." Computers, televisions, VCRs, stereos, copiers, and fax machines are common electronic products. Many of these products can be reused, refurbished, or recycled.







Migrant workers in Guiyu, China, scavenge used electronic equipment, which often contains highly toxic material. Photograph: Jim Puckett/AP

Hi-technology and E-waste

Urban mining

60,000 waste cell phones = 1 kg Gold



=

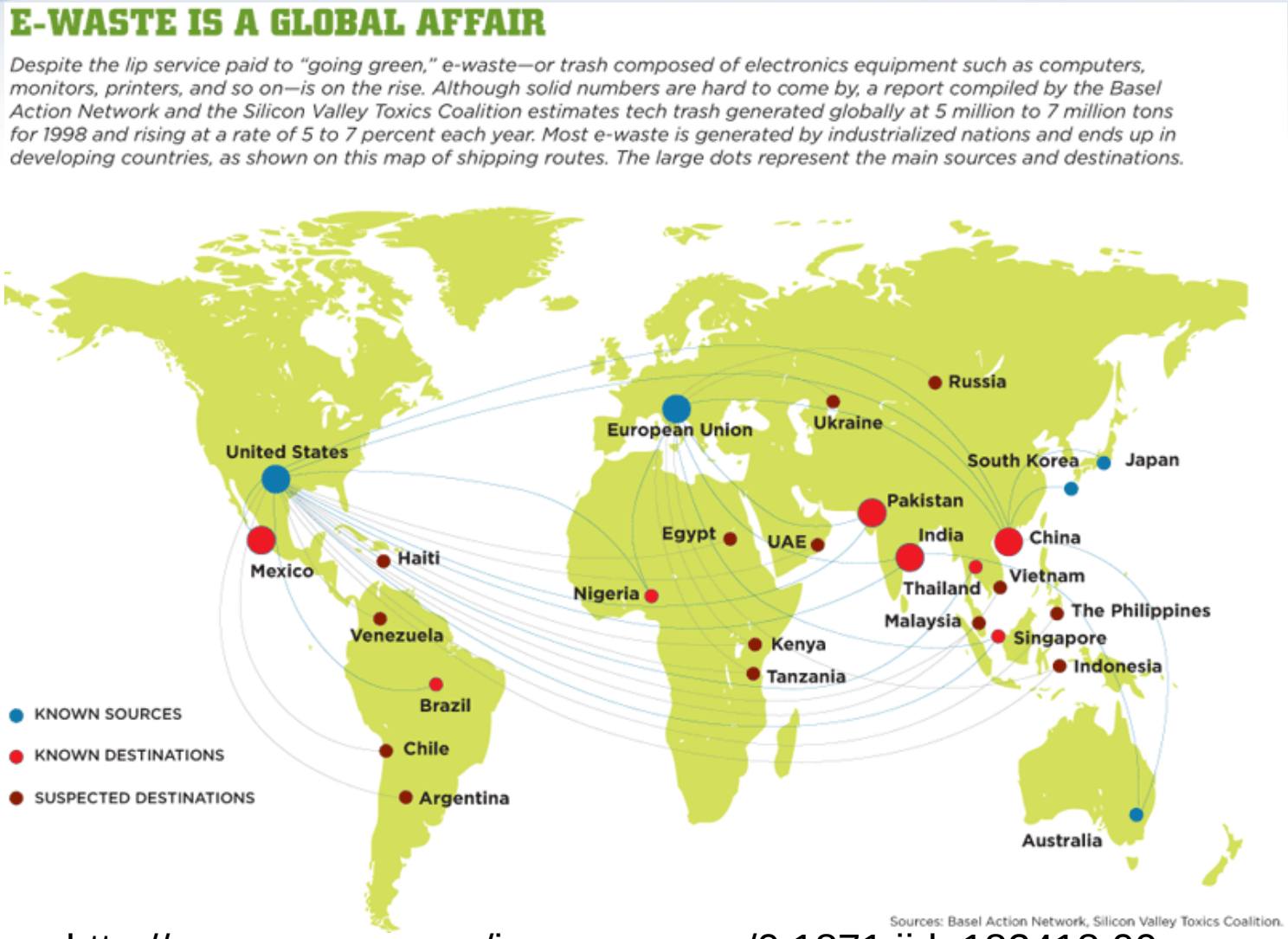


China discards almost 100 million phones each year

= China wastes 1,500Kg of Gold, 30,000Kg Silver every year
(30,000 EURO/1kg, 45,000,000 euro; 500 euro/kg silver, 15,000,000

http://mcxindia.info/2012/03/30/china-wastes-1500kg-of-gold-30000kg-silver-every-year/

E-waste problem



http://www.pcmag.com/image_popup/0,1871,iid=182418,00.asp

E-waste problem



http://www.foxnews.com/tech/2014/03/06/welcome-to-hell-photographer-documents-africas-e-waste-nightmare.html



http://www.smithsonianmag.com/science-nature/burning-truth-behind-e-waste-dump-africa-180957597/







http://www.theafronews.com/zimbabwe-the-e-waste-basket-of-the-region/

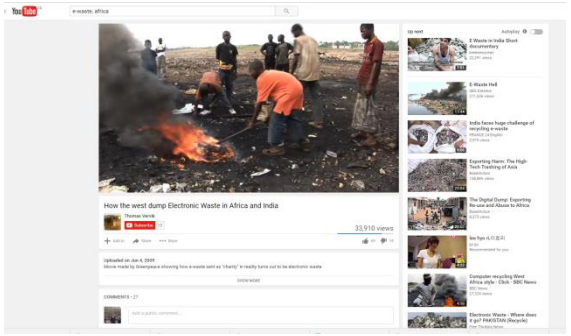
E-waste problem

- **Youtube video about E-waste issue**

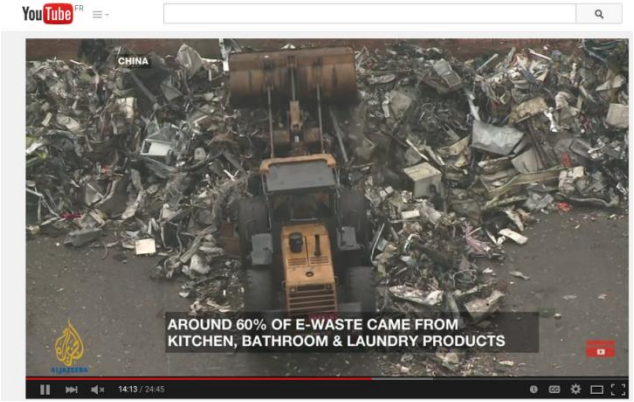
https://www.youtube.com/watch?v=5A5zVNpkuzk

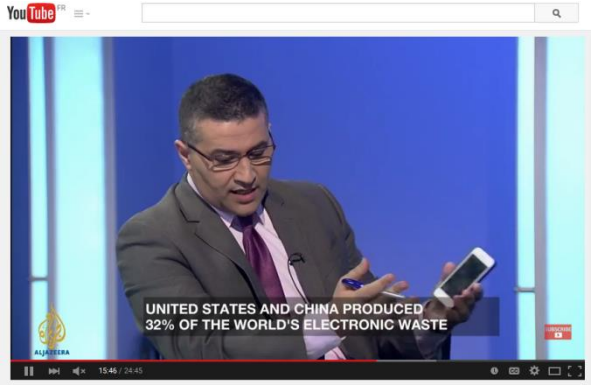






https://www.youtube.com/watch?v=fCVaiSk8idI

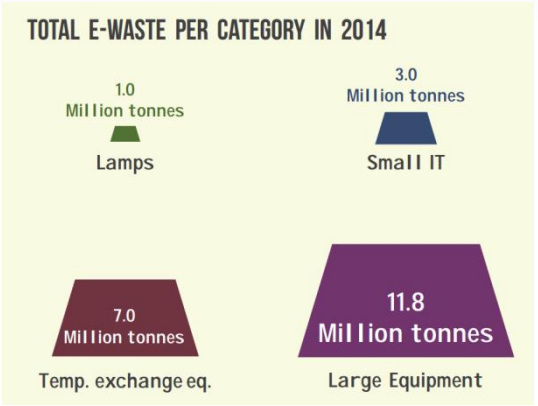


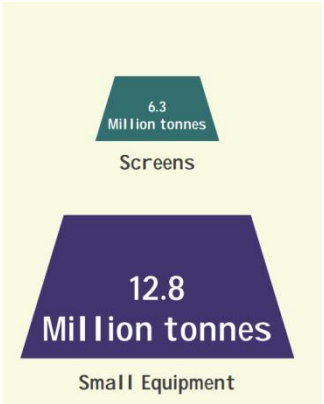




E-Waste Generation per category, continent, per inhabitant (2014)







Baldé, C.P., Wang, F., Kuehr, R., Huisman, J. (2015), The global e-waste monitor – 2014, United Nations University, IAS – SCYCLE, Bonn, Germany.

Some suggestions

- E-waste recycling facility and system
- Safe, easy and environmental friendly recycling system
- Small and compact size E-waste recycling and valuable resource recovery equipment
- Busininess, appropriate technology
- Others????

