IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

BRAJESH KUMAR DUBEY

DEPARTMENT OF CIVIL ENGINEERING

During this week (Week-1)

- Introduction to the course – Course Overview

about me…

- Brajesh Dubey, PhD, FIE, C.Eng
  - B.Tech (Hons) in Civil Engg; IIT, Kharagpur, India
  - Worked as a consulting engineer at Engineers India Limited for 4 years, based in New Delhi
  - Graduate work leading to PhD from University of Florida in Environmental Engineering Sciences
  - Worked as Research Scientist in Florida for 2.5 years
  - Taught and did research in New Zealand (at UOA) for nearly 2 years
  - Faculty in USA and Canada for 6 years
  - Serving at IIT Kharagpur as Associate Professor since March 2015
  - http://scholar.google.ca/citations?user=gLXcah0AAAAJ
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  - https://twitter.com/wasteprof

Solid & Hazardous Waste Management

- generation of solid waste has been around for a long time
  - it is an inevitable part of the human condition, and
  - there have been problems with waste since the very beginning
- there are four basic means of dealing with waste:
  1. dumping
     - anywhere humans have existed
     - usually in low lying areas
  2. burning
     - often uncontrolled
     - recently, we have developed incineration with some controls
     - why? it saves space, reduces smell and pestilence
  3. recycling
     - recover beneficial components
     - separation for Hazardous Waste
  4. waste minimization
     - reduce resource & energy usage during manufacturing

History of Solid Waste

- uncontrolled dumping has been the cause of many problems in society over the centuries
- a good example is the Bubonic plague:
  - zoonotic disease (passed from animals to human) caused by Yersinia pestis
  - transferred mainly between small rodents and their fleas, but can be transmitted to humans when they come into contact with the fleas
  - in the 14th century it killed ~ 50% of the population of Europe (75 million)
- in the middle ages there were uncontrolled piles of garbage in, and around, cities
- this provided a great environment for rats and other disease carrying animals to prosper, providing ideal conditions for a variety of diseases to flourish:
  - leptospirosis, salmonellosis, toxoplasmosis, ...

Present Day

- a big component of waste management is the 3Rs

  - **reduce** – at the source
    - to make something smaller or use less
    - through education and enforcement
  - **reuse** – "re-use" materials in their original form instead of throwing away
    - use travel mugs; have a yard sale; donate old clothes, ...
  - **recycle** – divert part of the waste stream back into production
    - rather than throw it away
- Life-cycle Assessment has been suggested as a way to help solve waste problems
  - assess the environmental impact associated with all stages of a product's life cycle from "cradle-to-grave"
  - helps avoid a narrow outlook on environmental concerns
  - part of RCRA in the US

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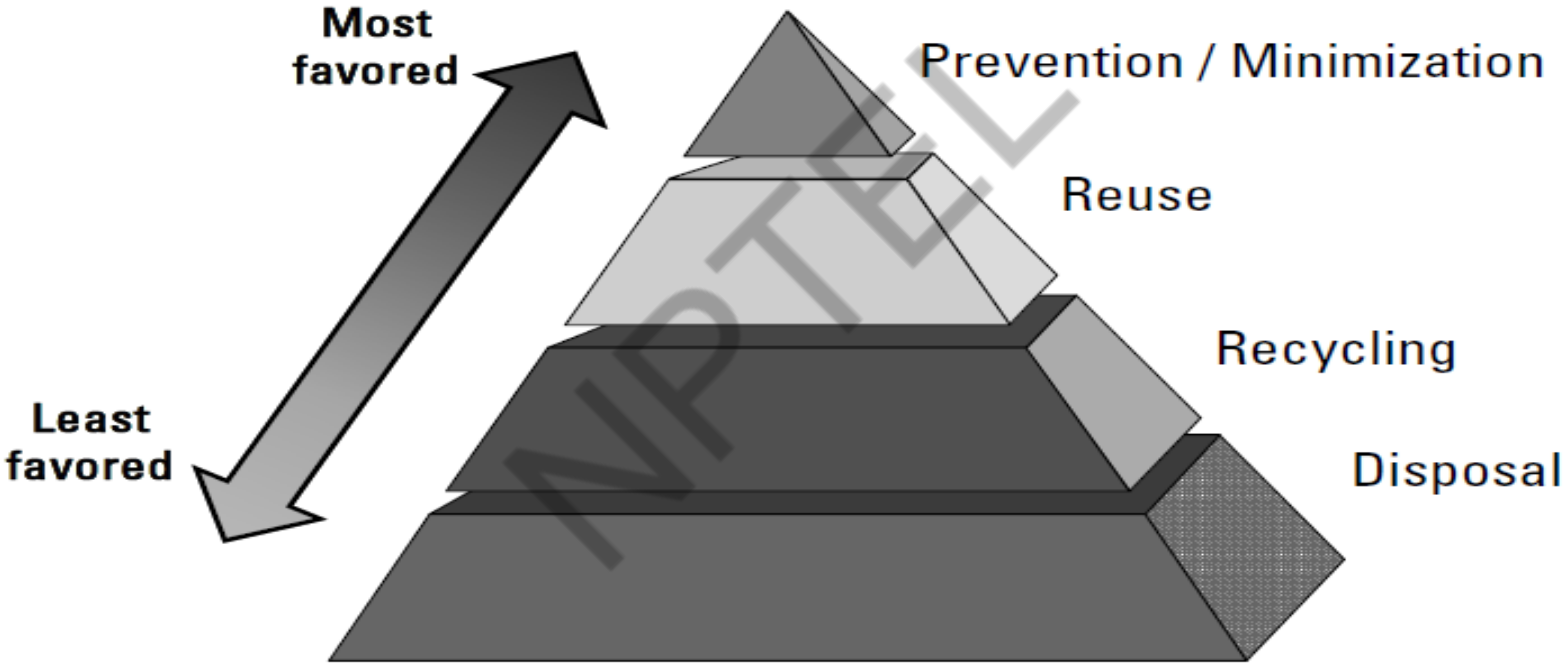
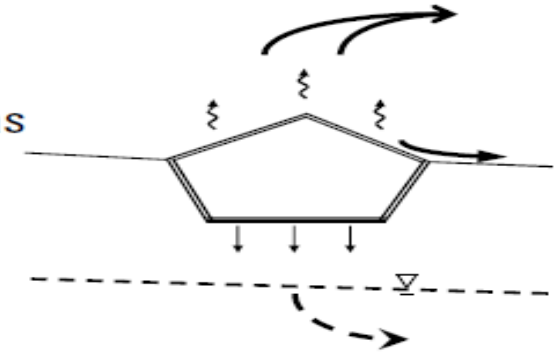
Present Day

- the waste management hierarchy:



Landfills

- landfills are the de-facto choice for waste management and they cause lots of problems for the environment
  - land usage, air, surface water, groundwater, pests (rats, seagulls), noise, ...
- leachate production can be a problem for groundwater
  - residual contaminants in the waste leach out and leak out of the landfill
  - highly toxic (~ 100 times stronger than sewage) and very odorous
  - can lead to groundwater contamination (downgradient of the landfill)
- methane production can be a problem for air
  - causes odour problems around the landfill
  - 25 times more powerful than other greenhouse gas
  - can be beneficial as a renewable energy source
- litter is unsightly during landfill operations
  - the area around an active landfill has to deal with lots of debris that is blown around



Alternatives to Landfills

- there are few, and most are used in conjunction with landfills

1. incineration
   - positive:
     - large volume reduction (therefore, less landfill space used, or just more time to fill up the same approved volume)
     - potential energy recovery
   - negative:
     - still troubled by air pollution (extensive stack gas control)
     - some materials don't burn
     - ash plus these non-combustibles require subsequent landfill disposal
     - siting problems are equal to those of landfills
2. recovery of reusable products, compost, refuse-derived fuels
   - markets are limited
   - short term costs > landfills, in many cases
   - residue still remains a problem for disposal

Solid Waste Management

- so, what is solid waste management?
- it is a comprehensive program of waste prevention, recycling, composting and disposal
- this includes management of:
  - waste generation,
  - storage,
  - collection,
  - transfer and transport,
  - processing,
  - disposal, ...

Solid Waste Management

- another important aspect of solid waste management is that you need to have an understanding of:
  - public attitudes – toward waste, recycling, landfills, ...
    - an important component of landfill design is Public Consultation
  - administration – of the entire system
  - planning – formulating plans (tasks and schedules) to design, construct, operate, expand, ... landfills and other waste management facilities or programs (composting, 3Rs, HHW drop-off, ...)
  - legislation – all under the watchful eye of the regulatory community (local, regional, provincial)

Solid Waste Management

- as a result, solid waste management is impacted by many different disciplines:
  - political science,
  - geography,
  - economics,
  - public health,
  - sociology,
  - communications,
  - material science,
  - archeology,
  - engineering ← just a small component in the process

Solid Waste Management

- and in the design and management process, takes into consideration best practices in:
  - planning,
  - public health,
  - economics,
  - engineering,
  - conservation,
  - aesthetics,
  - environmental issues, ...

6 Elements of a Waste Management System

1. waste generation – waste is material that has no further value to its owner and is thrown away
   - some has further value to others (reuse)
     - chemical ingredients,
     - electronic parts,
     - compost for your garden, ...
   - some is just waste (disposal)
     - food wrapping,
     - product containers,
     - old computers, ...
- as technology develops, something that was previously considered waste may have renewed value:
  - food to CH_4 for energy production

6 Elements of a Waste Management System

2. handling, separation, storage and processing at source
   - best place is at the source!
   - placed in various containers (blue, green, white)
   - separate the valuable from the waste (paper, metals, plastics)
   - avoid contamination from hazardous waste
   - proper on-site storage for health reasons
   - need the cooperation of citizens for separation to work
     - at home and at work
     - houses vs. condos vs. apartments
     - much of it can be contaminated, and must be processed at a facility
   - on-site processing can include composting and compaction into various containers

6 Elements of a Waste Management System

3. collection
   - gathering waste and recyclables
   - transport to recycle, transfer or disposal facilities
   - interim disposal at transfer station
   - the location is a function of distance to disposal site
   - considered the most expensive component of solid waste handling
   - industries are handled separately from municipal waste

6 Elements of a Waste Management System

4. separation, processing, transformation
   - could be as simple as opening bags
   - special facilities to separate recyclables into various streams
     - includes shredding for easier handling
     - compacting to reduce shipping costs
     - screens and mechanical separators
   - incineration and composting considered transformation of the waste

6 Elements of a Waste Management System

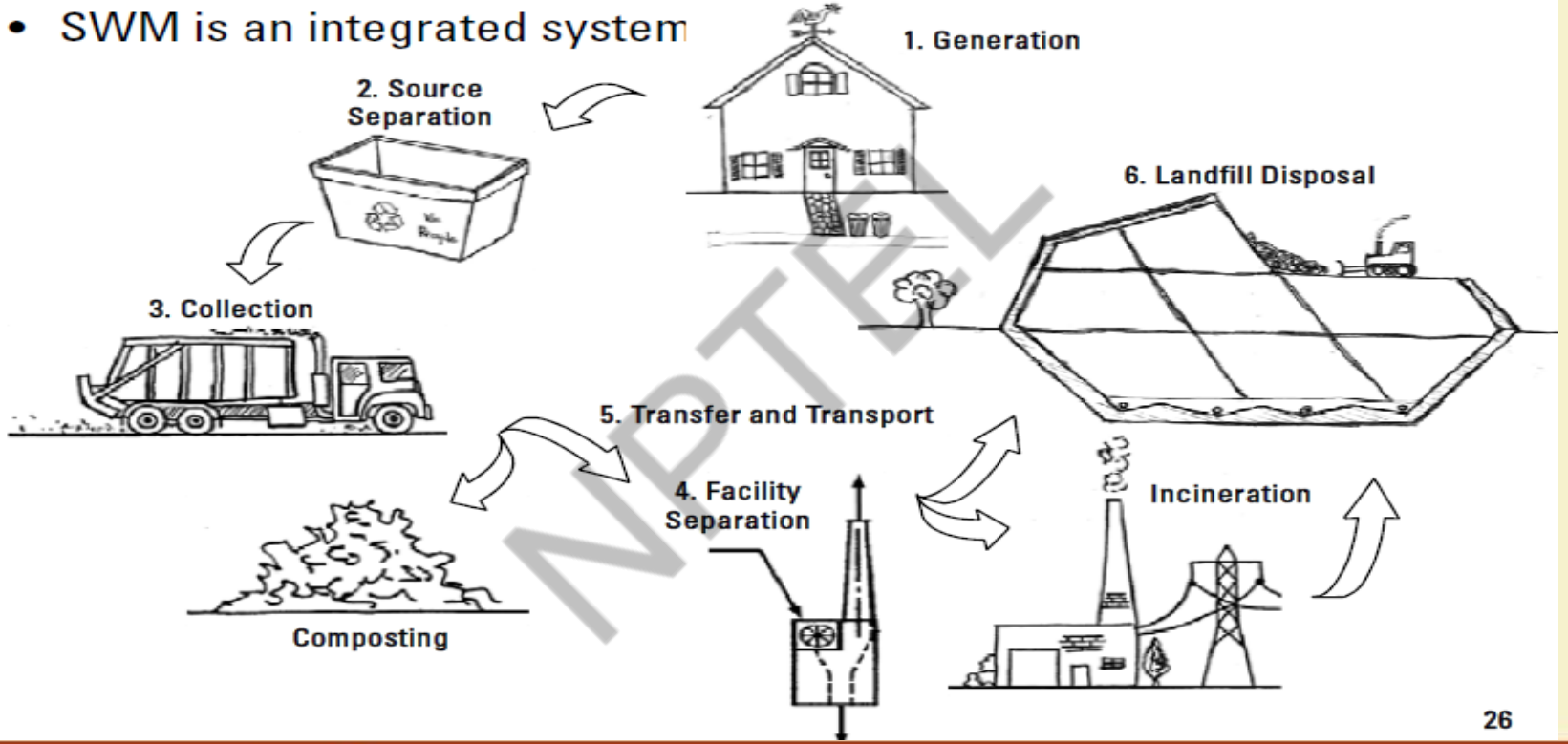
5. transfer and transport
   - smaller collection vehicles used to bring the waste to final destination (landfill, incinerator) or to a transfer station
   - compacted further and transported farther
     - truck
     - rail (cheapest)
     - barge

6 Elements of a Waste Management System

6. <u>disposal</u>
   - landfilling of waste or the residue of processed/transferred waste
   - considered the final destination with large liability
   - a modern landfill is an engineered facility to safely contain waste
   - provides for maximum CH_4 production and minimal escape of leachate
     - the quicker the CH4 is produced, the faster the landfill is stabilized, allowing the site to be "reused"
   - incinerated waste would have different characteristics

Summary

- SWM is an integrated system



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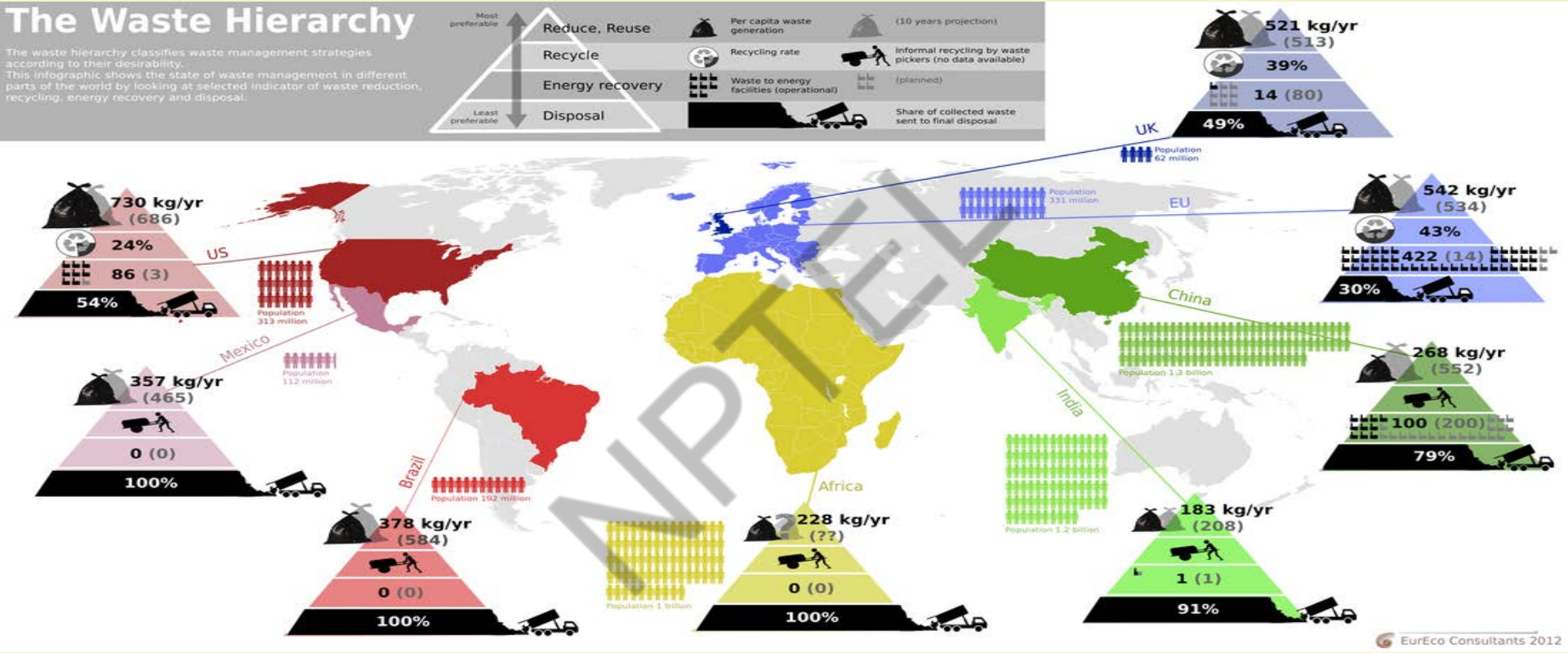
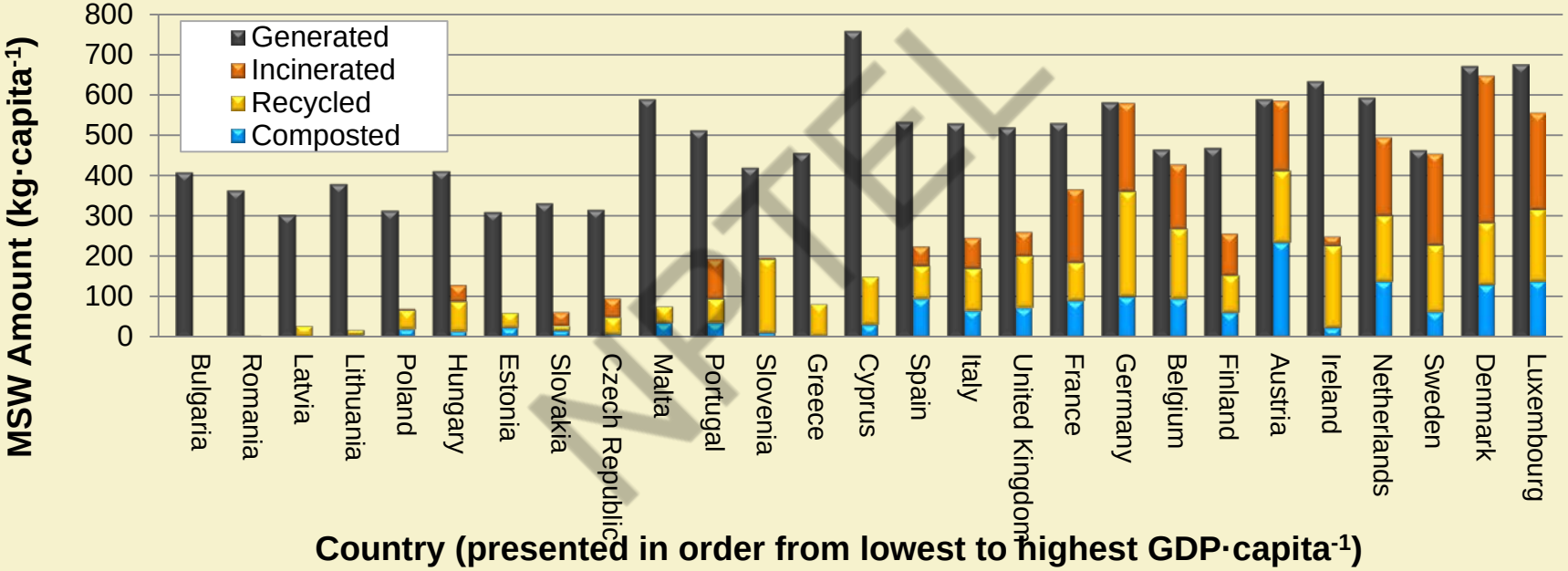

The Waste Hierarchy
The waste hierarchy classifies waste management strategies according to their desirability.
This infographic shows the state of waste management in different parts of the world by looking at selected indicator of waste reduction, recycling, energy recovery and disposal.
Most preferable
Reduce, Reuse
Recycle
Energy recovery
Disposal
Least preferable
Per capita waste generation
(10 years projection)
Recycling rate
Informal recycling by waste pickers (no data available)
Waste to energy facilities (operational)
(planned)
Share of collected waste sent to final disposal
521 kg/yr
(513)
39%
14 (80)
49%
UK
Population 62 million
730 kg/yr
(686)
24%
86 (3)
54%
US
Population 313 million
Population 331 million
EU
542 kg/yr
(534)
43%
422 (14)
30%
China
Population 1.3 billion
Mexico
Population 112 million
357 kg/yr
(465)
0 (0)
100%
268 kg/yr
(552)
100 (200)
79%
Brazil
Population 192 million
378 kg/yr
(584)
0 (0)
100%
Africa
Population 1 billion
228 kg/yr
(??)
0 (0)
100%
India
Population 1.2 billion
183 kg/yr
(208)
1 (1)
91%
EurEco Consultants 2012

Case Study – Europe

- EU Landfill Directive (1999/31/EC) aims to reduce biodegradable waste going to landfill by:
  - 25% in 2006 (2010)
  - 50% in 2009 (2013)
  - 65% in 2016 (2020)
- Applies to all EU member countries

Case Study – Europe

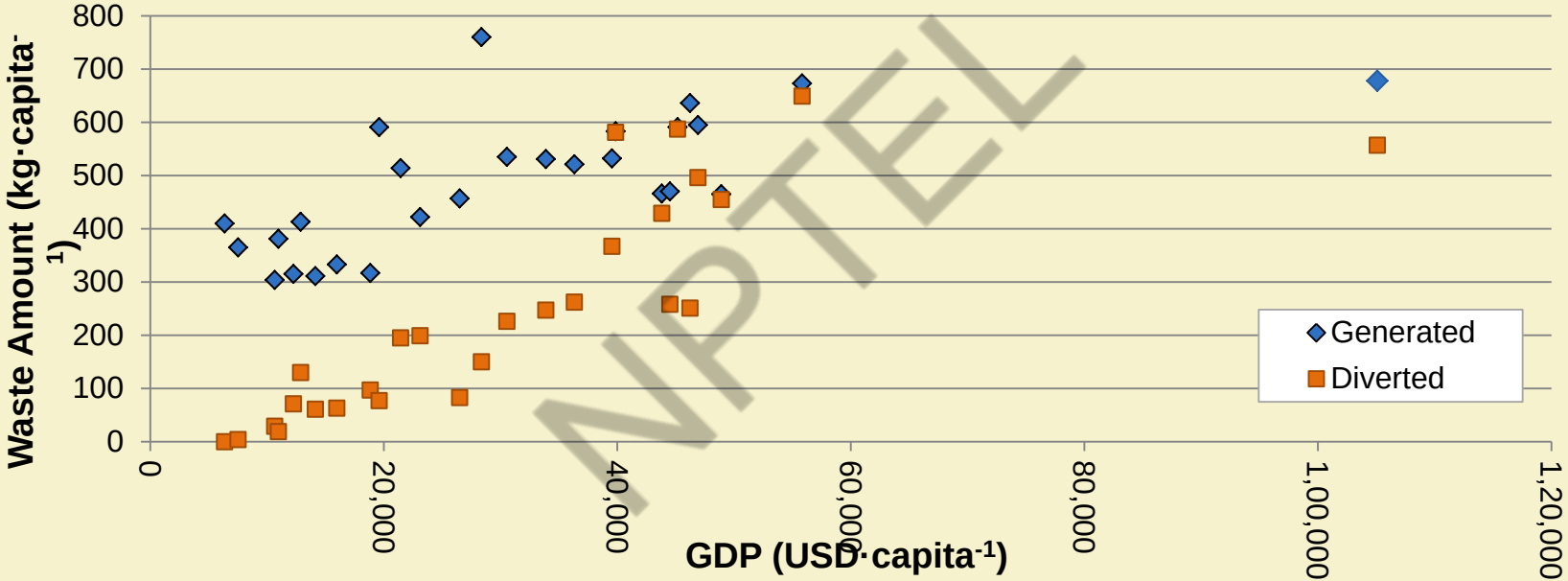
- Despite the Landfill Directive, there are vast differences in waste diversion (including organic) between EU countries



- **Source:** Eurostat
- MSW = Residential and ICI waste streams

Case Study – Europe

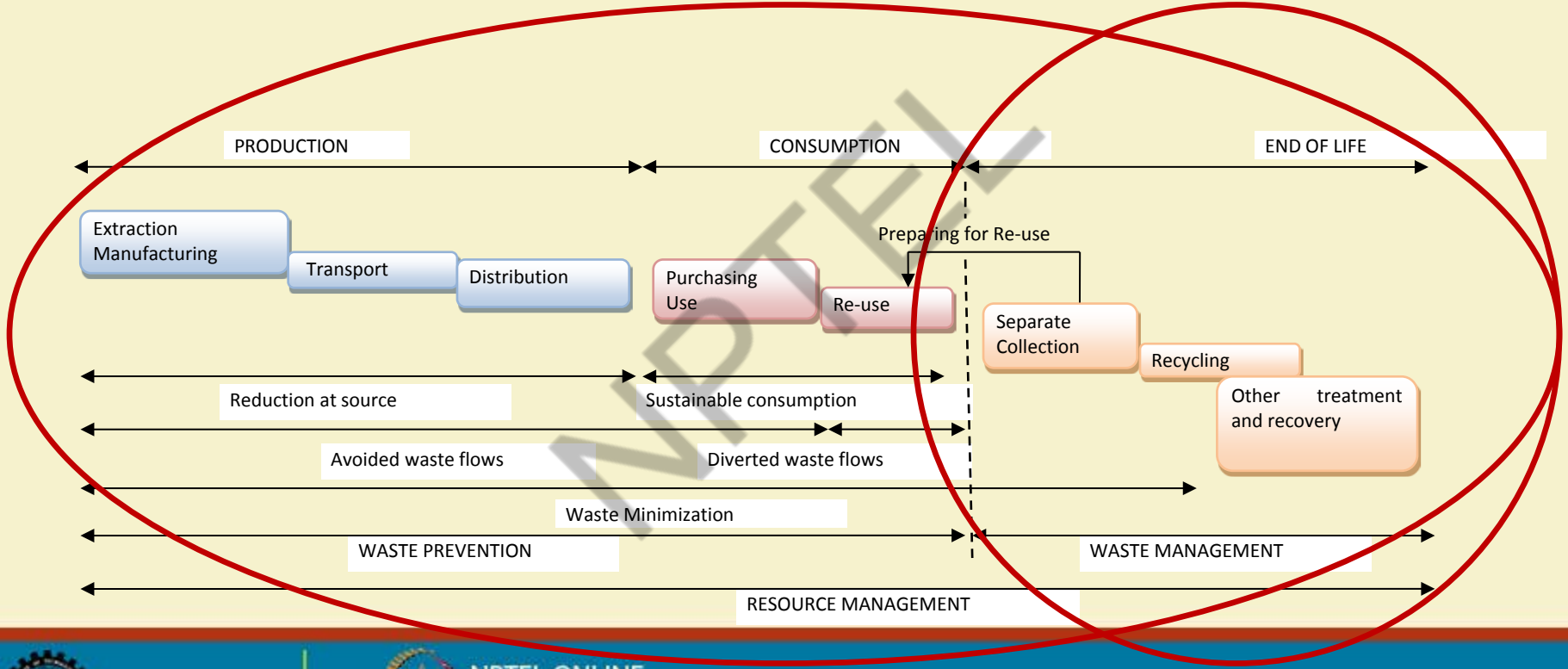
- Even with waste directive, diversion function of GDP

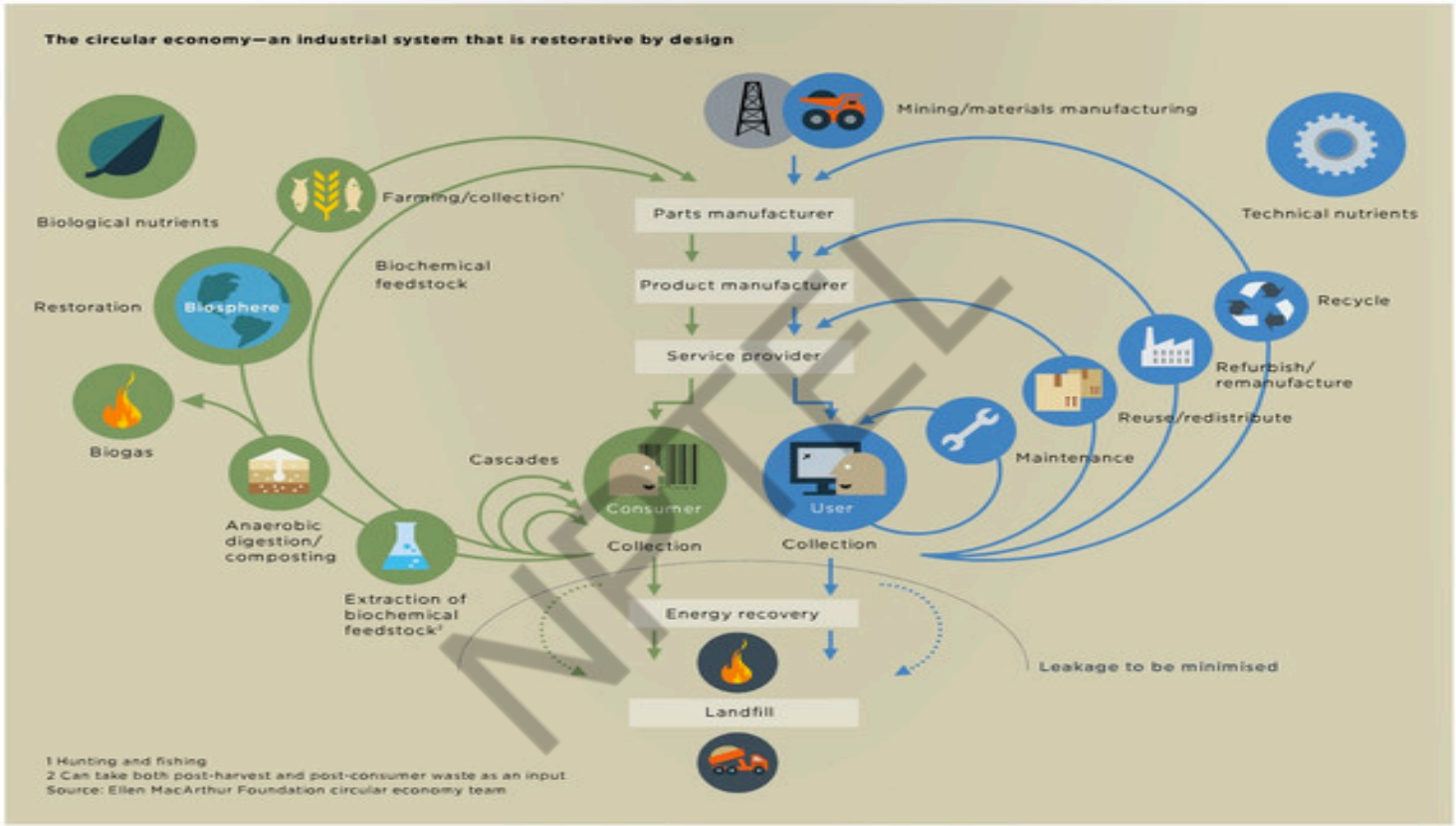


- **Source:** Eurostat
- MSW = Residential and ICI waste streams

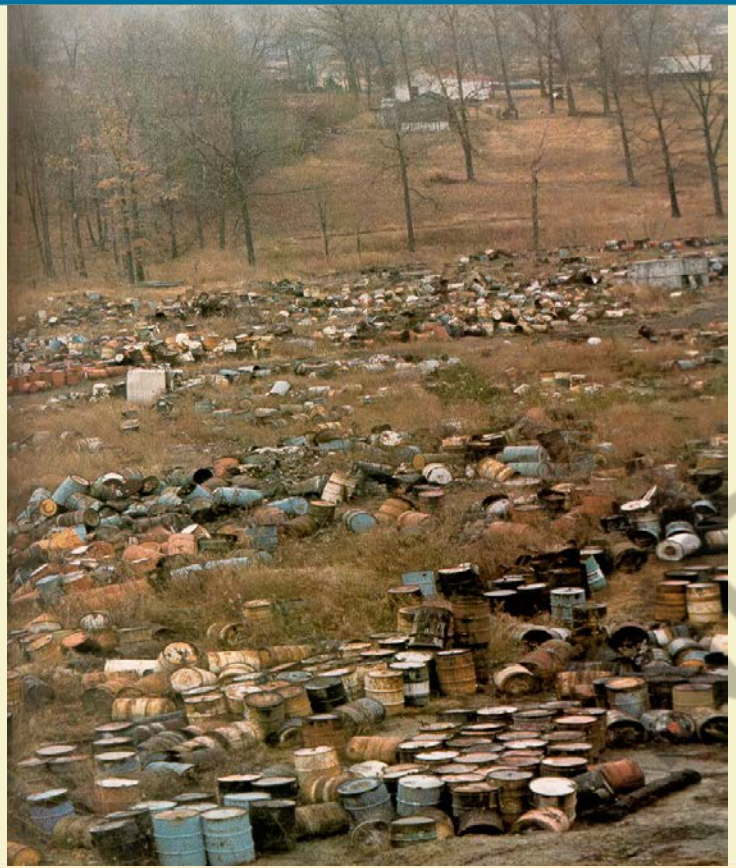

HOW LONG UNTIL IT'S GONE?
Estimated decomposition rates of common marine debris items
Waxed Carton
3 months
Cardboard Box
2 months
Apple Core
2 months
Foamed Buoy
50 years
Plastic Grocery Bag
10 – 20 years
Plywood
1 – 3 years
Disposable Diaper
450 years
Cigarette Butt
1 – 5 years
Newspaper
6 weeks
Paper Towel
2 – 4 weeks
Wool Socks
1 – 5 years
Plastic Bottle
450 years
Photo-degradable
Beverage Holder
6 months
Aluminium Can
200 years
Fishing Line
600 years
Styrofoam Cup
50 years
Tin Can
50 years
Plastic Beverage Holder
400 years
Glass Bottle
undetermined
Cotton Shirt
2 – 5 months
Estimated individual item timelines depend on product composition and environmental conditions.
Source: NOAA (National Oceanic and Atmospheric Administration), US / Woods Hole Sea Grant, US
Graphics: Oliver Lüde / Museum für Gestaltung Zürich, ZHdK

Moving towards Resource Management




The circular economy—an industrial system that is restorative by design
Mining/materials manufacturing
Biological nutrients
Farming/collection[1]
Technical nutrients
Parts manufacturer
Biochemical feedstock
Product manufacturer
Restoration
Biosphere
Recycle
Service provider
Refurbish/ remanufacture
Biogas
Reuse/redistribute
Maintenance
Cascades
Consumer
User
Anaerobic digestion/ composting
Collection
Collection
Extraction of biochemical feedstock[2]
Energy recovery
Leakage to be minimised
Landfill
1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

Why Do We Care How Solid Waste is Regulated/Managed?



Source: Brown, Michael, “Drums of Death”, *Audubon*, 120 July 1980.

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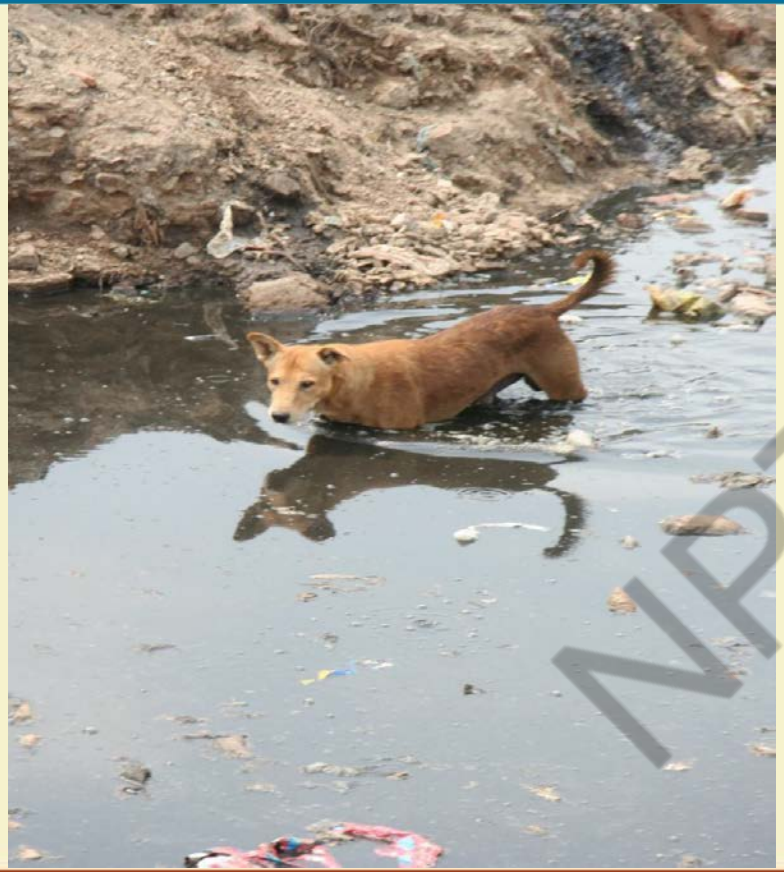
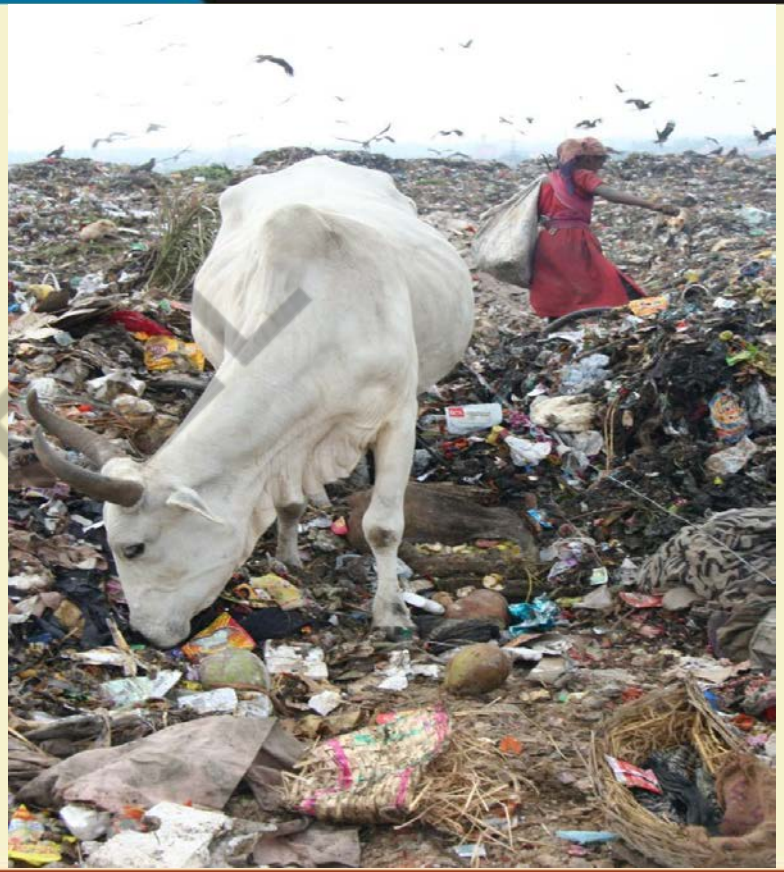
MAERSK SEALAND
HYUNDAI
UASC
CMA CGM
YANG MING


Frooti





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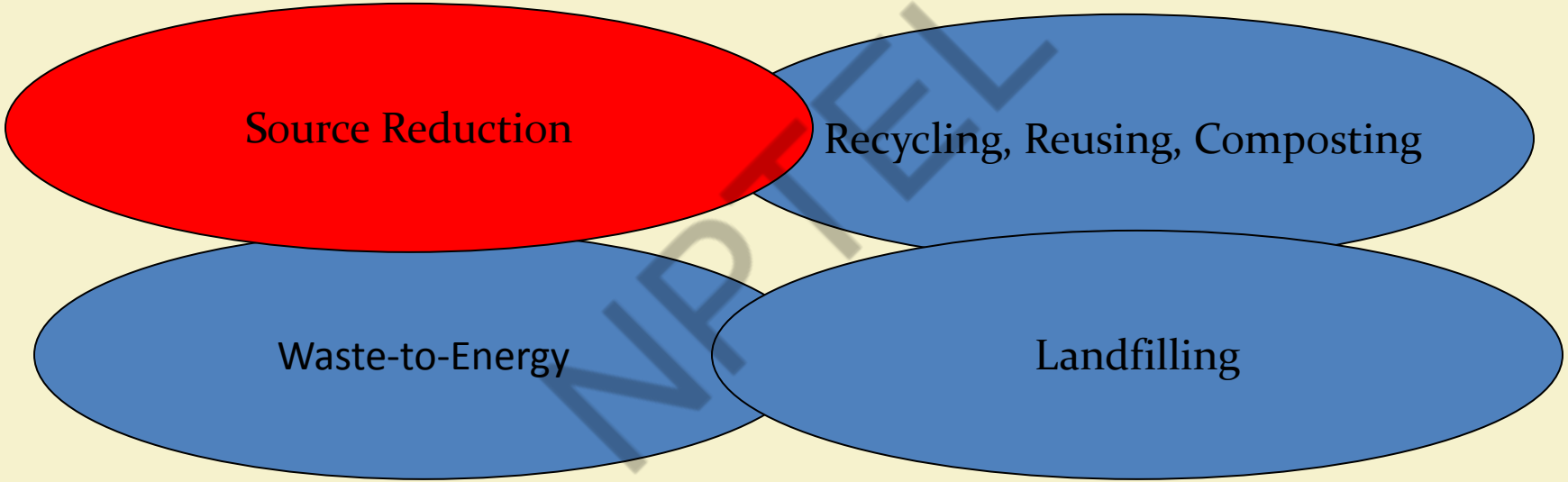
Integrated Waste Management



Source Reduction

- Reduce material use in product manufacture
- Increase useful life through durability and reparability
- Decrease toxicity
- Material reuse (pallets, containers, etc.)
- Efficient consumer use of materials

Source Reduction

- EPA estimates that 50% of the waste quantity can be reduced with source reduction
- Should not be a substitute of one problem for another
- Packaging is 50% of waste volume and 1/3 of waste weight
  - Paper and plastics
  - Spend more on food packaging than farmers net income
  - Replace w/smaller, lighter, degradable material

Recycling

- Returning raw material to market
- Pros:
  - Save precious resources
  - Lessens need for mining of virgin materials
  - Lowers environmental impact of mining/processing
  - Stretch landfill capacity
  - Improve efficiency of incinerators and composting facilities

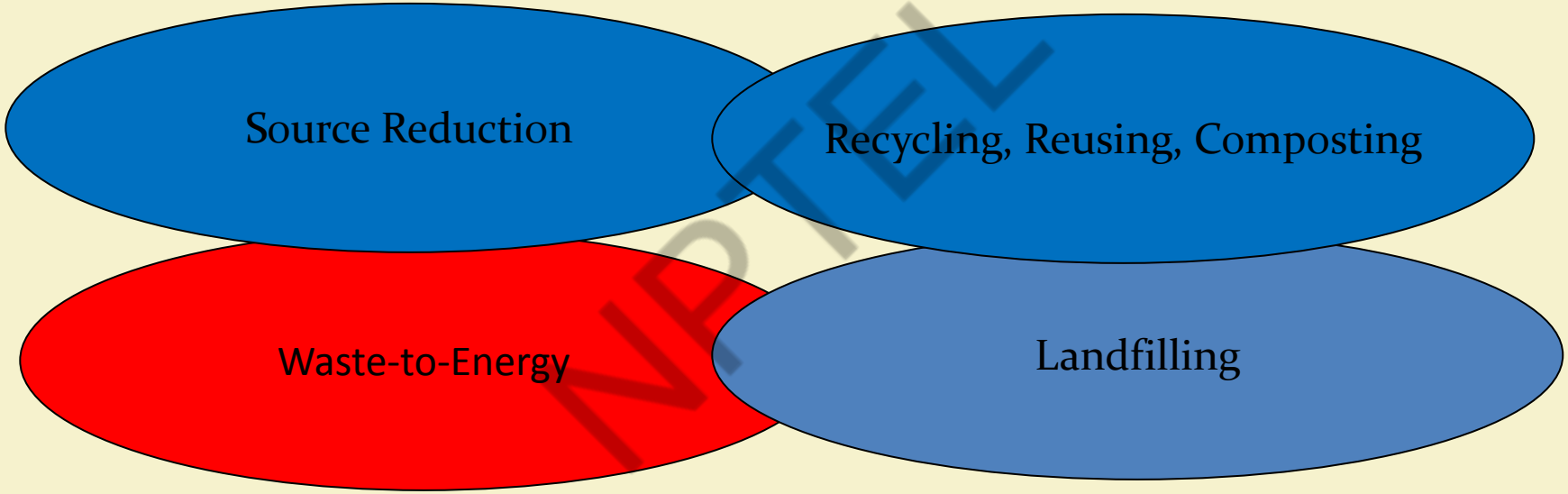
Recycling

- Cons:
  - Poorly managed sites can result in Superfund sites
    - Waste oil recycling, newspaper de-inking, solvent and metal recycling
    - Can result in contamination of soil, groundwater, air
  - Require stable market
  - Only works if it is convenient
    - Curbside pick-up
    - Drop off centers
    - Mail back programs

Composting

- Natural decomposition of organic material
  - Need organic, water, oxygen
  - Not use preserved wood, human wastes, bones, meat, fat, certain weeds
- Individual
- Municipal

Integrated Waste Management



Waste to Energy (Combustion)

- There are three methods in which energy can be recovered from incineration processes;
  - Heat
  - Electricity
  - Cogeneration (harnessing of useful heat and electricity from one power plant)

Waste to Energy (Combustion)

- The two most common types of combustion that are used at these facilities are;
  - Mass Burning / Preparation
  - Combustion of Refuse Derived Fuel (RDF)

Waste to Energy (Combustion)

- Mass Burning / Preparation
  - MSW enters the facility and is inspected for the presence of non-combustible, hazardous, and explosive materials. These materials are separated from the waste stream
  - The waste stream is then fed into the combustion chamber along with forced air for “processing”.
  - Some of these facilities can process 3000 tons of MSW a day. They can however be scaled down to a smaller size if necessary

Waste to Energy (Combustion)

- Combustion of RDF;
  - All hazardous, iron containing or otherwise non-combustible materials are removed from the waste stream.
  - The remainder of the waste stream is shredded
  - The material is then burned or further processed into pellets or cubes to be used as fuel in other furnaces
  - In some instanced the materials can be processed and packaged for re-sale to other facilities for use as fuel


STOP

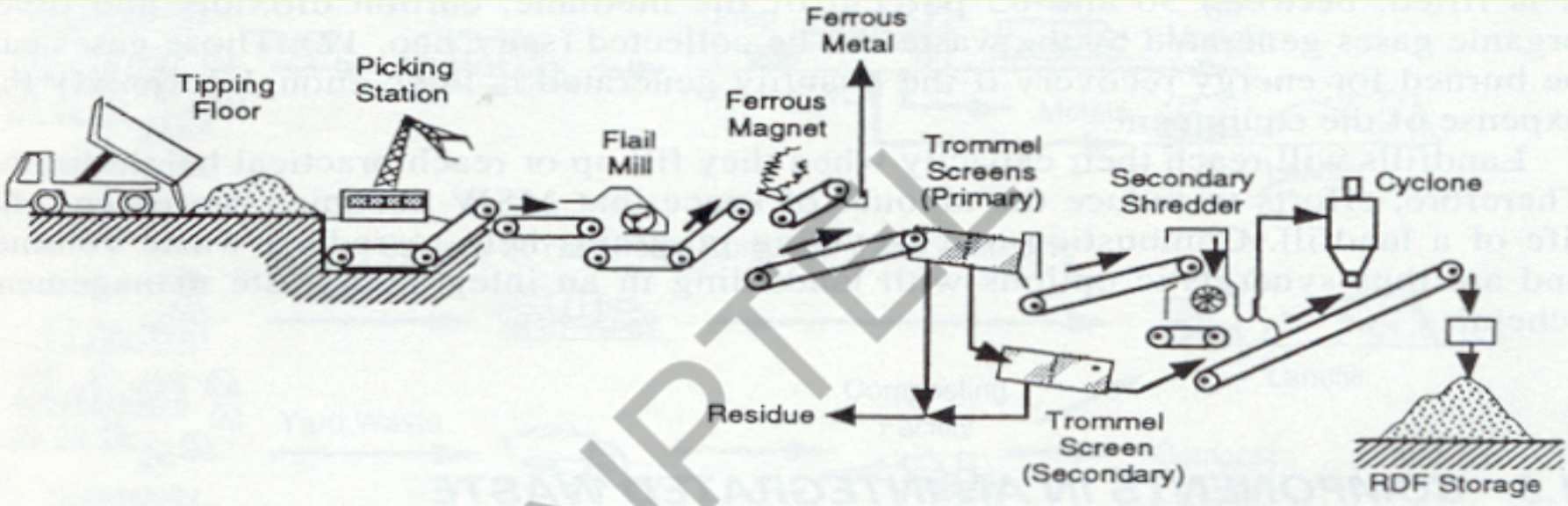
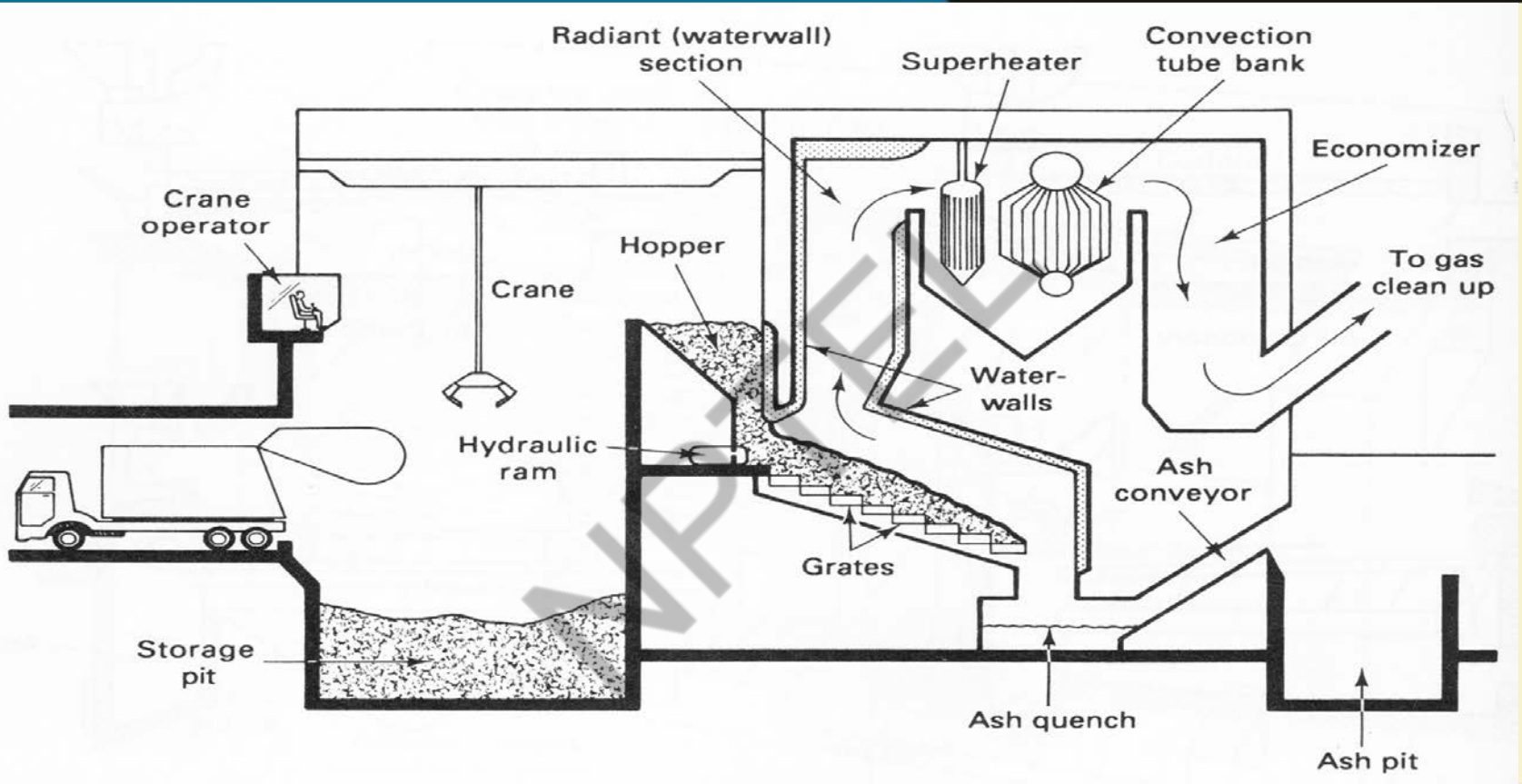
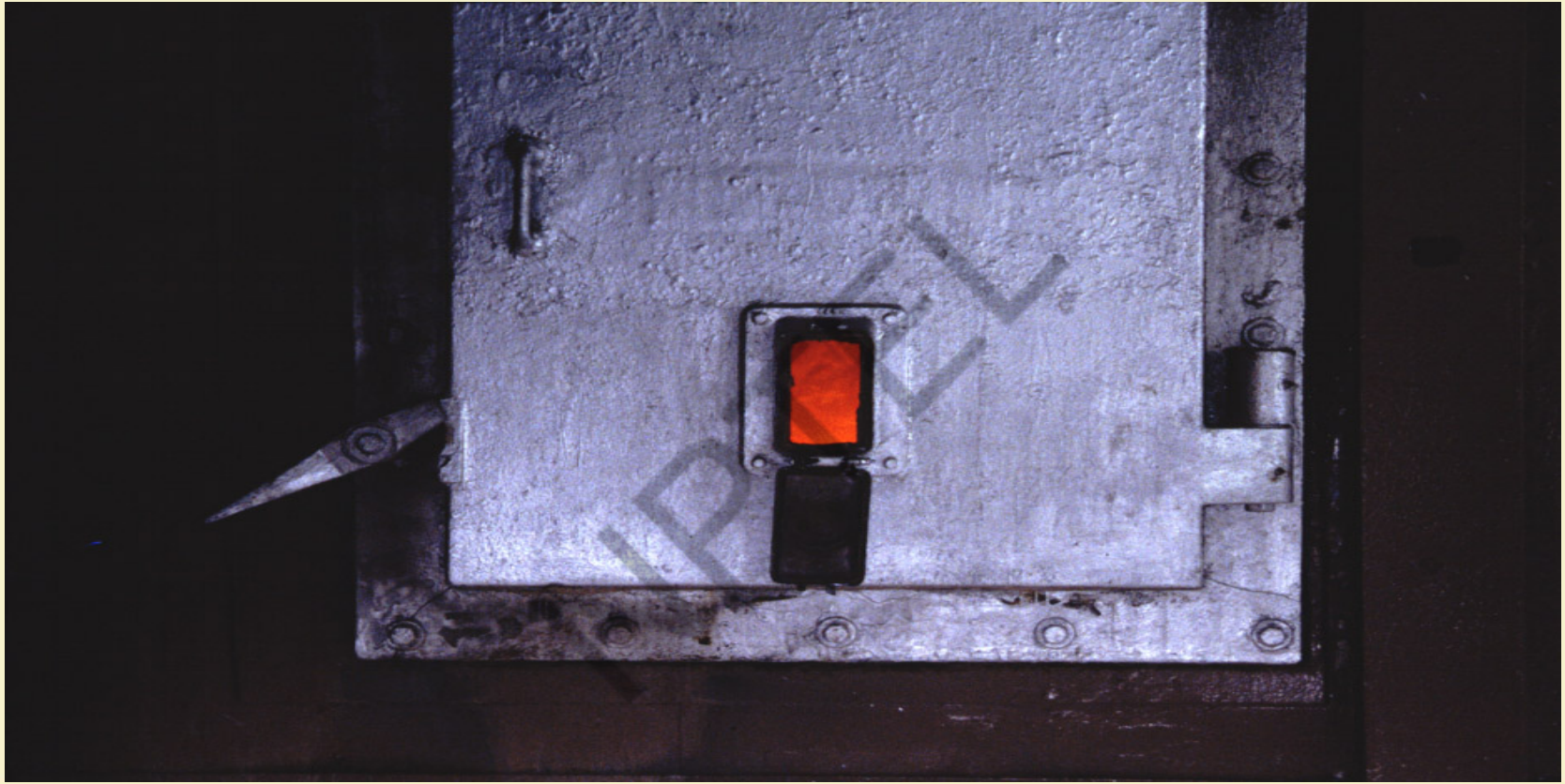


FIGURE 1.4 RDF processing system.


Radiant (waterwall) section
Superheater
Convection tube bank
Economizer
Crane operator
Crane
Hopper
To gas clean up
Water-walls
Hydraulic ram
Ash conveyor
Grates
Storage pit
Ash quench
Ash pit

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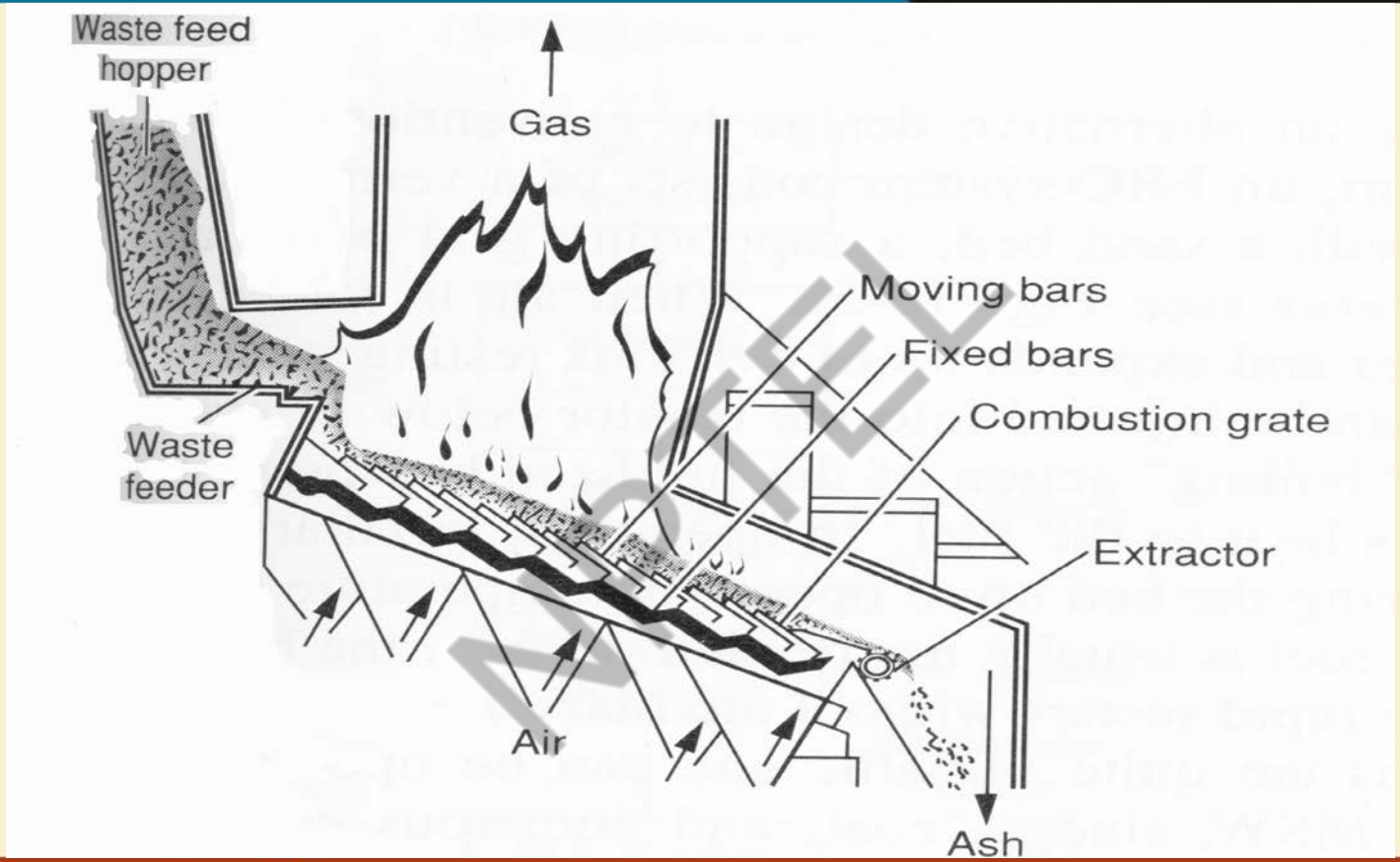
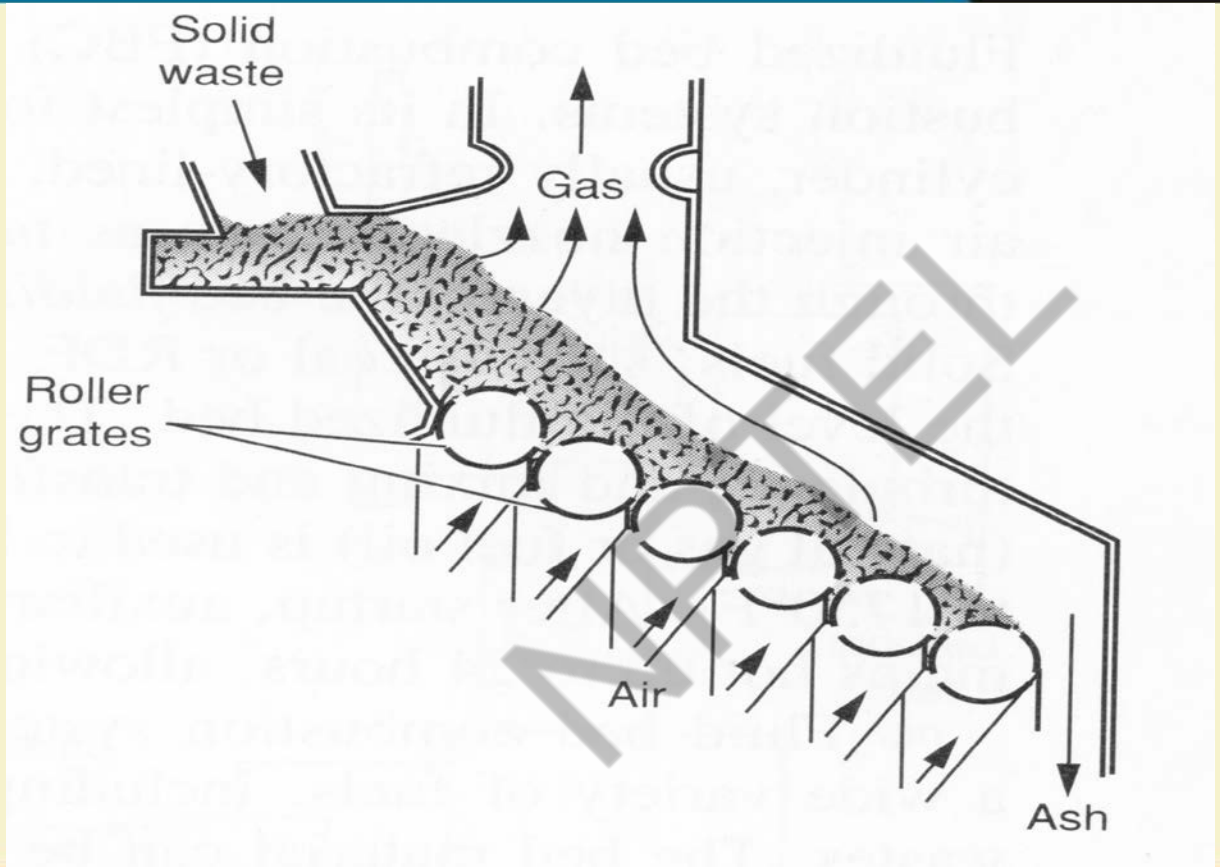


Grates



Ash Landfill

Waste to Energy (Combustion)

- What are some of the pros and cons of Combustion to Energy Operations?

- What are some of the environmental impacts of these types of facilities? (both good and bad)

Waste to Energy (Combustion)

PROS:

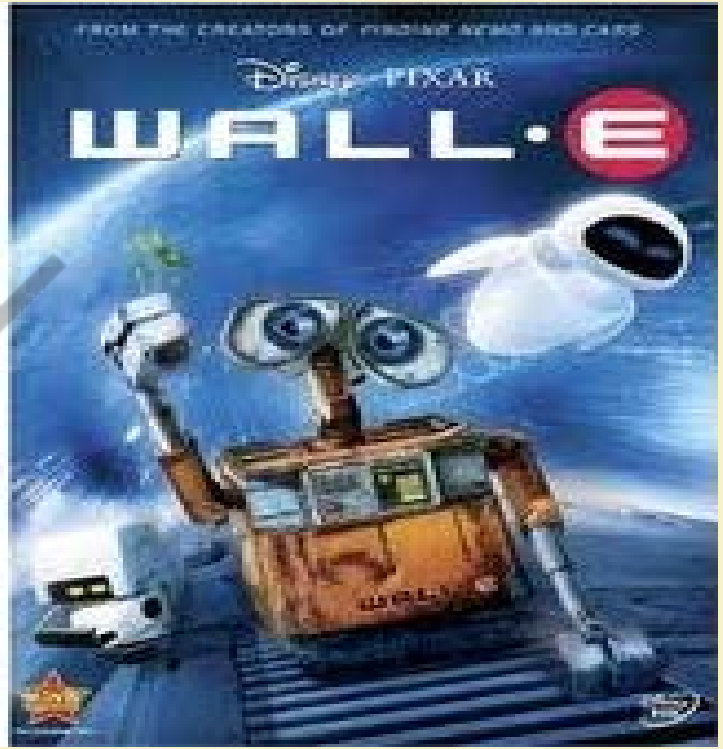
- Reduce volume of waste
- Recover useful energy
  - Steam
  - Waste
- Incinerator ash can be used in building material

Waste to Energy (Combustion)

CONS:

- Cost
- High degree of sophistication needed to operate safely and economically
- Public perception of safety
  - Stack emissions
  - Toxicity of ash


THE BREAKOUT COMEDY OF THE SUMMER
TOY STORY 3
3D
2010


FROM THE CREATORS OF FINDING NEMO AND CARS
Disney PIXAR
WALL·E

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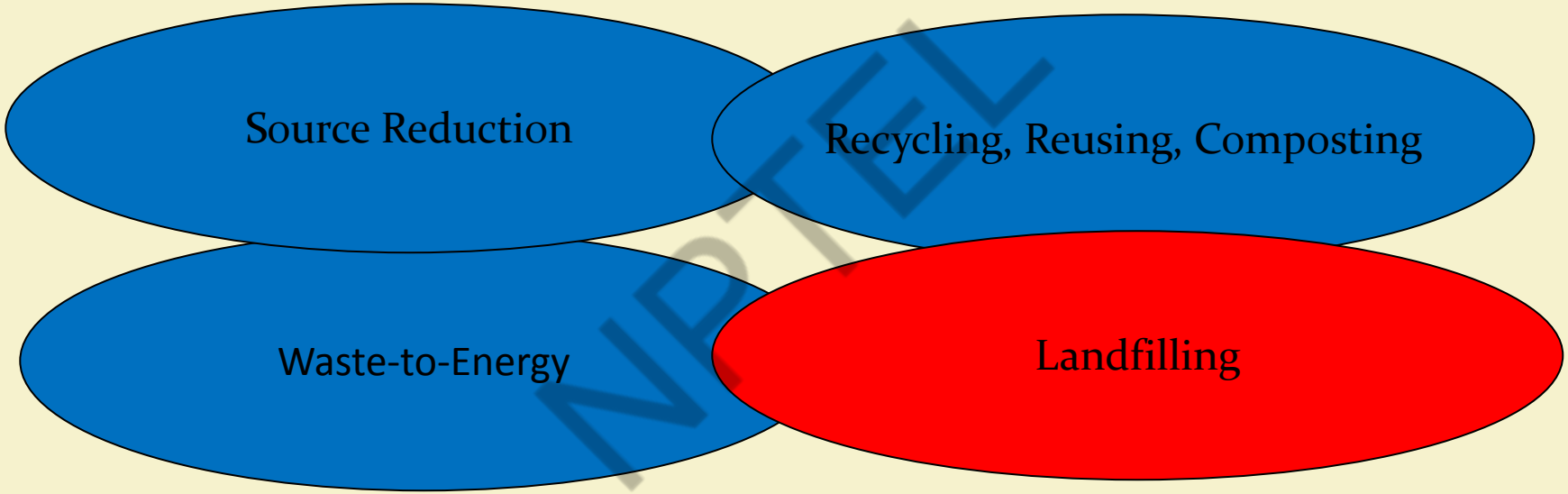
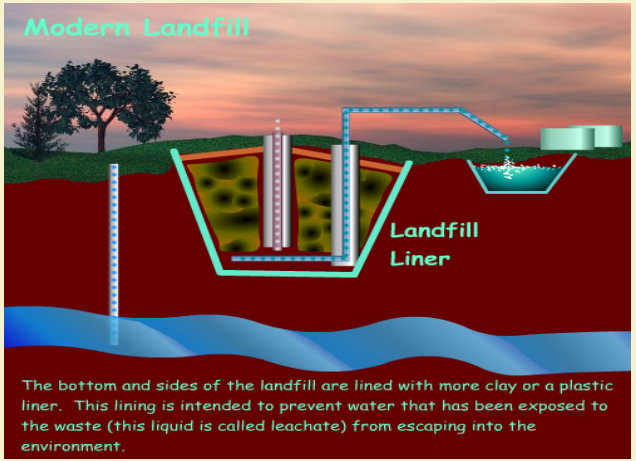


Landfilling

- 50-70% of municipal solid waste is landfilled
- Modern landfill vs traditional landfill
  - No longer take hazardous waste
  - Do not receive bulk liquids
  - Gas control systems
  - Liners
  - Leachate collection systems
  - Groundwater monitoring systems
  - Better sited



Landfill Problems

- Physical amount and disposal sites
- Costs to collect, handle, and dispose
- Litter
- Odor
- Insects (flies, cockroaches) & rodents
  - food
  - harborage
- Resource lost

What is a Landfill?

- Concept fostered in early 20th century
- An area of land that has solid waste deposited on it in such a quantity to noticeably change the surface elevation.

Why to use a landfill?

Potential Landfill Problems

- Landfill can present problems with respect to:
  - Spread of disease
  - Odors
  - Fires

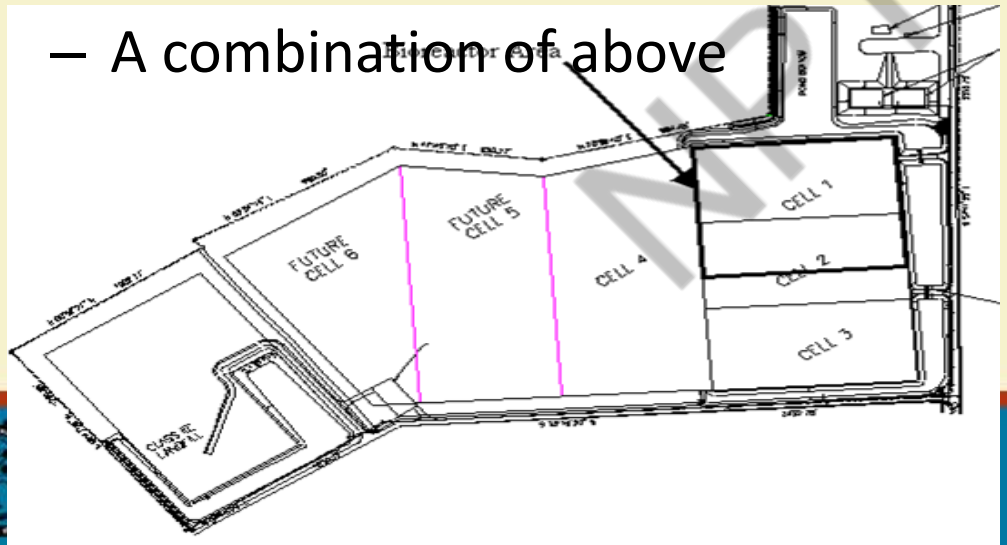
  Controlled by sanitary landfill techniques

  - Contamination of groundwater
  - Gas emissions

  Controlled by modern landfill design

Sanitary Landfill

- Landfills may be:
  - Excavated and filled
  - Fill existing depressions
  - Built up from the ground
  - A combination of above



- Operate landfills in a controlled safe fashion
  - Use cover soil
  - Excavate cells
  - Compact the waste
  - Control access

Modern Landfills are Engineered Structures

- Designed to Contain Leachate and Minimize Release of Pollutants from the Landfill

Leachate

- Leachate is the liquid (or wastewater) that forms when water (rainfall, groundwater) travels through solid waste
- Leachate can migrate into underlying groundwater, resulting in contamination
- Leachate can contain many different chemicals, depending on what is in the solid waste

Landfill Gas

- Landfill gas consists primarily of methane and carbon dioxide

- Results from the anaerobic decomposition of biodegradable solid wastes

Typical Regulatory Requirements

- Location restrictions
  - Airports
  - Wetlands
  - Fault lines
  - Unstable areas
  - Endangered species

Typical Regulatory Requirements

- Liners -- Low permeability barrier layers
  - Compacted soil (clay)
  - Geomembranes (plastic)
  - Composites of both
- Liner keep leachate from migrating out of the landfill
- Leachate must be collected and removed

Single Liner System

- One liner consisting of compacted soil ***or*** geomembrane

Composite Liner

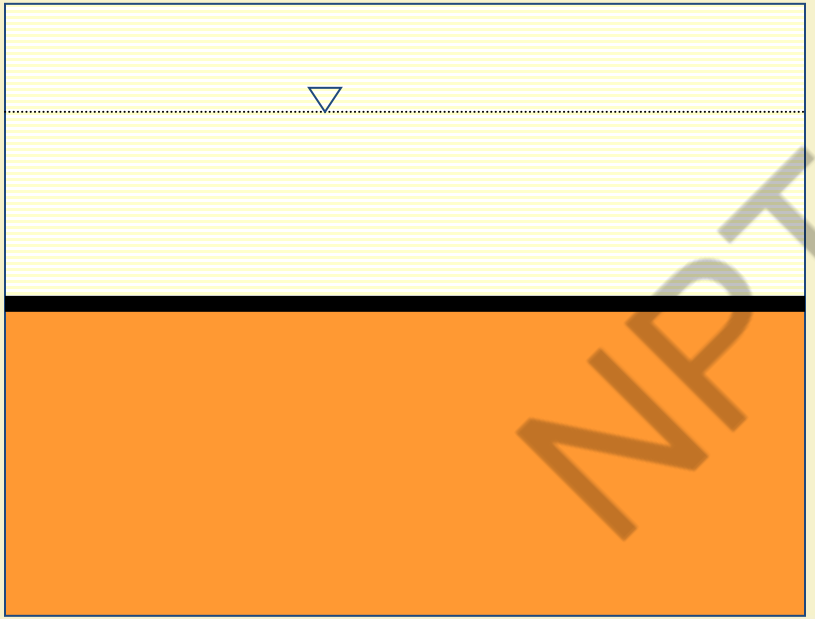
- A single liner consisting of compacted soil and geomembrane in intimate contact

Double Liner

- A liner system with low permeability barrier layers with a leak detection system layer in between. The upper and lower components are either compacted soil, geomembrane, or composite.

Typical Composite Liner

Single Composite Liner



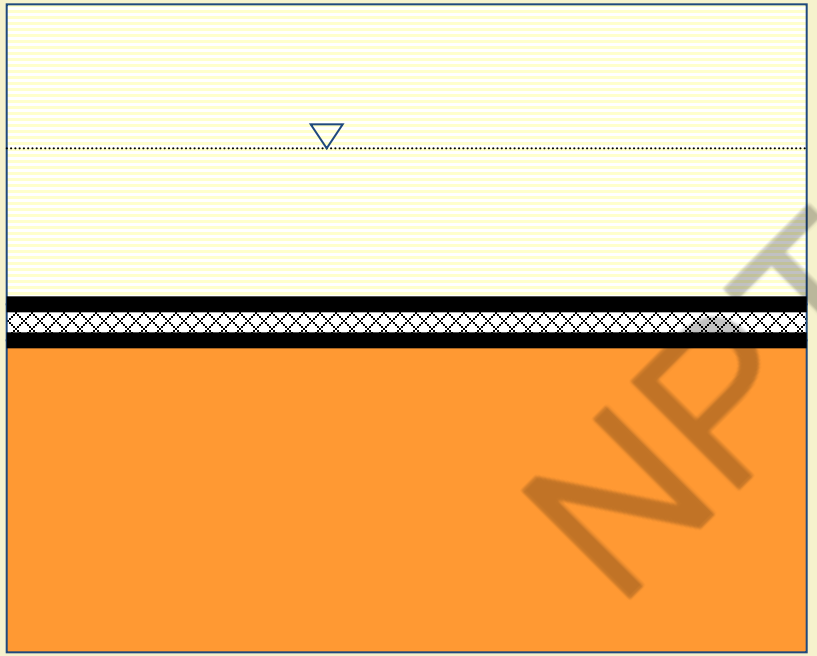
2 ft drainage material
Designed to maintain
less than 1ft head on liner

60 mil HDPE
Geomembrane

2 ft compacted soil
$K <= 10^{-7}$ cm/sec

1 mil = 0.001 inch

Double Liner



2 ft drainage material
Designed to maintain
less than 1ft head on liner

HDPE Geomembrane

Geonet

HDPE Geomembrane

3 ft compacted soil
$K <= 10^{-7}$ cm/sec

Types of Geomembrane Materials

- HDPE
- PVC
- VLDPE
- PP

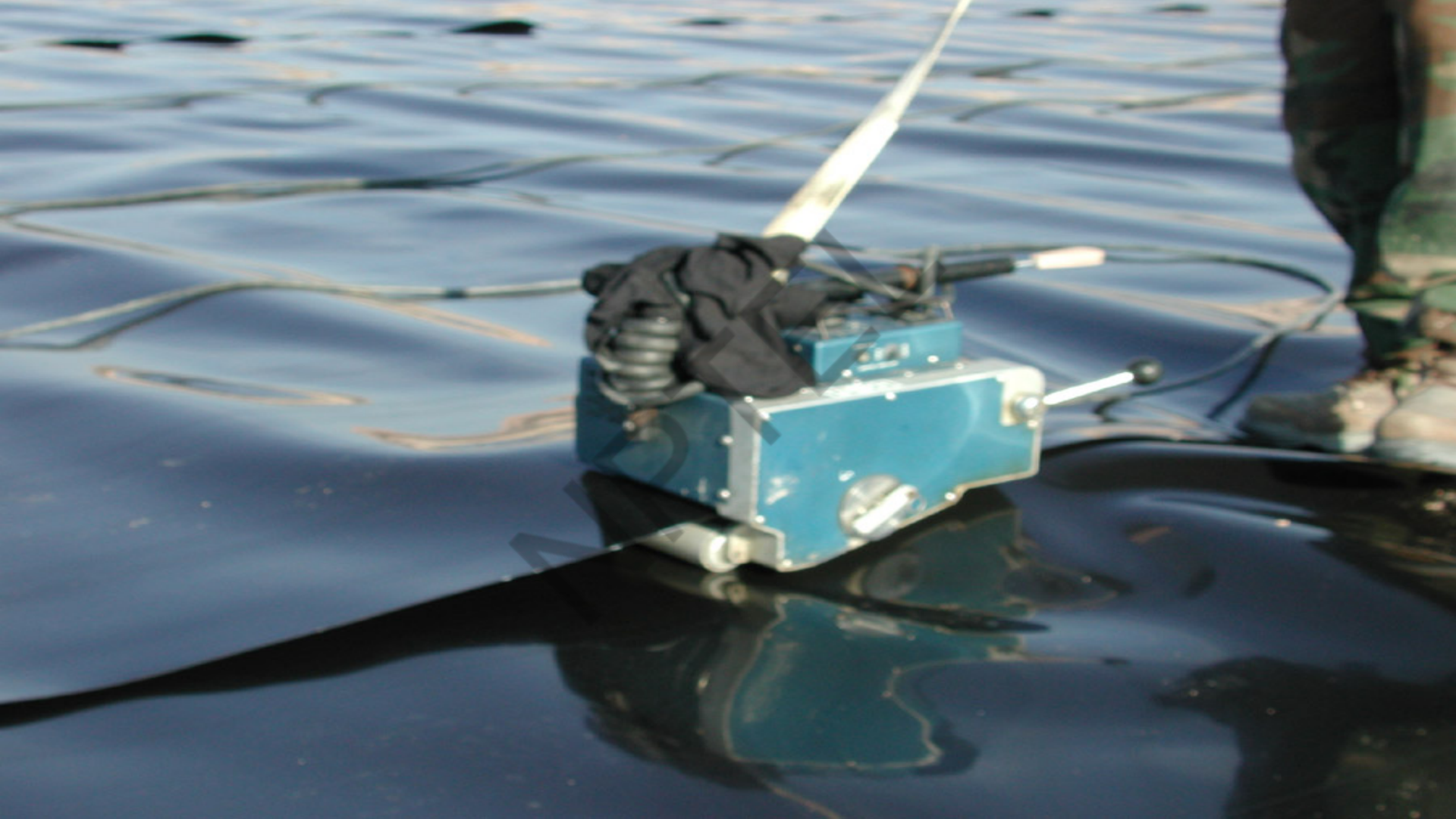
Unloading Soil


CP-563D
9ZW00149

Grading Top - Roller


DEERE


544H
DEERE



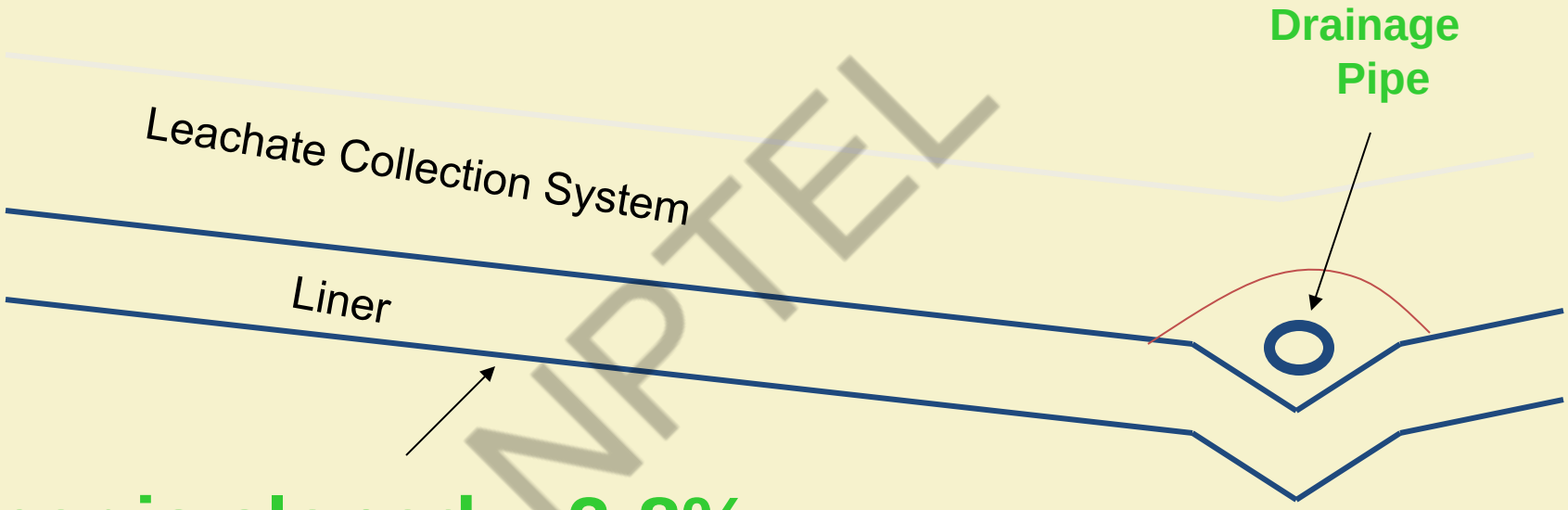
How do you Remove Leachate from the Landfill?

- Drain as much as you can by gravity (liner system and pipes)
- Pump from low points
  - Penetration through the liner
  - Pumps inside landfill

Leachate Collection System

- If leachate flow is intercepted or impeded by a liner, then it should be removed from the landfill by use of a leachate collection system. A leachate collection system is a high-permeability layer designed to transmit leachate from the liner.

How is Leachate Removed



Liner is sloped ~ 2-8%

What is a Geonet?

- A synthetic (HDPE) material used for drainage of liquids. It is a has transmissivity in the later direction.


AIRBUS

What is a Geotextile?

- A geosynthetic textile that is used in many civil engineering applications. It separates fine granular materials from coarse granular materials, plus it allows water to flow through.

INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

End of Week-1