Solid Waste Engineering

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Exercise No. 1 – what is waste?

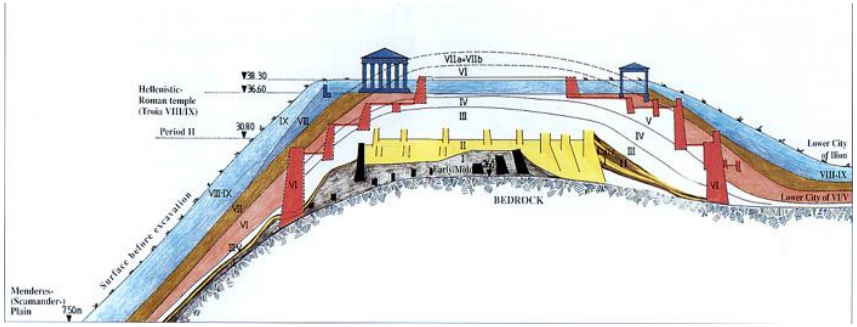
- Make groups of 3-4 persons
- Grab a marker and a white board
- Think about the definition of waste
  - Technical sense
  - Economical sense
  - Regulatory sense

Definition of waste – What is waste?

Waste, now and then…

Edible food packaging for space travel

A cutaway view of ancient Troy shows how the city literally managed to surmount its garbage problem



Solid Waste Engineering

1. Waste classification and characterization
2. Collection / Transport /Recycling
3. Combustion and energy recovery
4. Landfills

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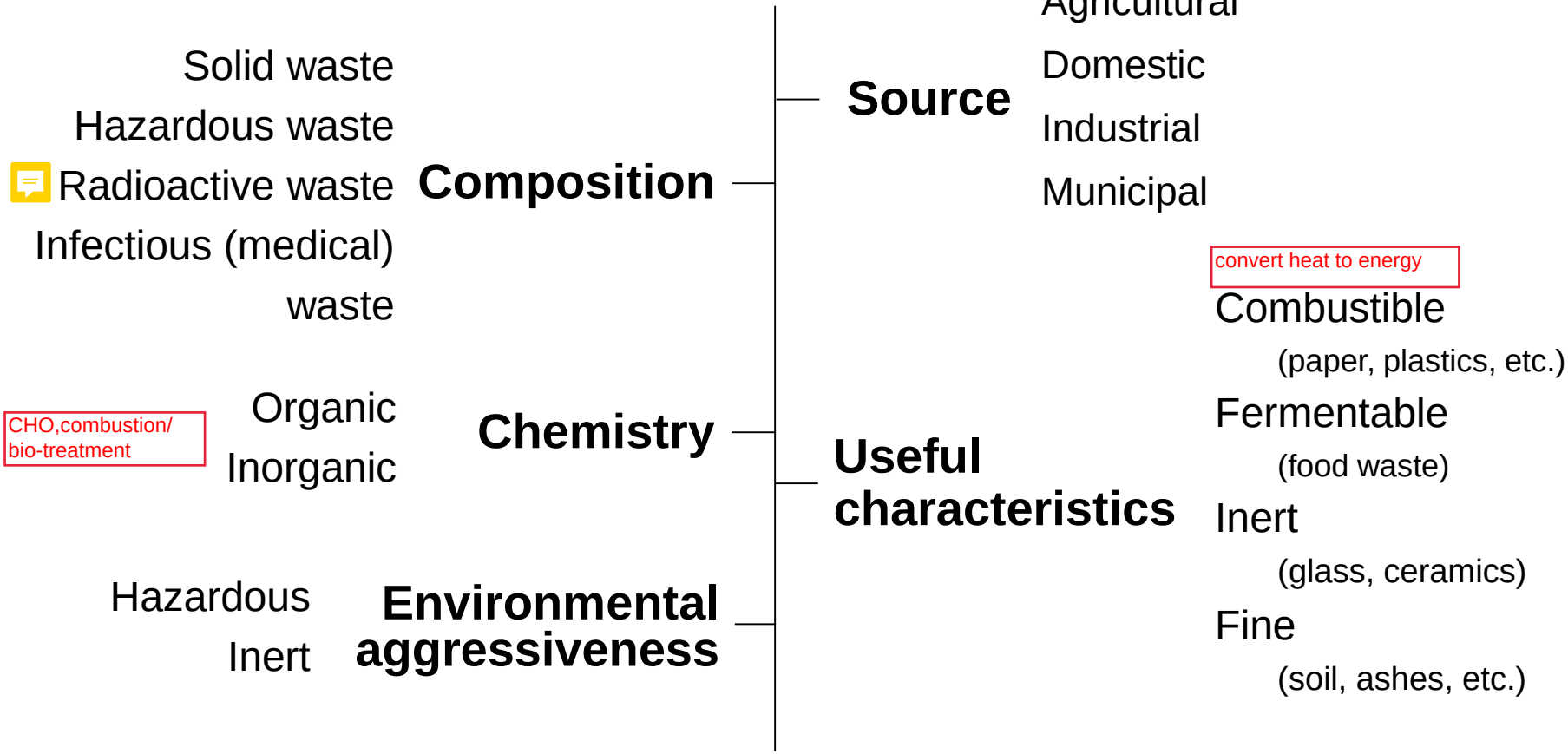
Ways to classify waste



Municipal solid waste (MSW)

Refuse = Solid waste generated by households

- *Garbage* = food waste
- *Rubbish* = everything else including recyclables
- Household *hazardous* waste
- Yard (or green) waste originating with individual households

Non refuse = not collected with household refuse

- construction and demolition debris
- water and wastewater treatment plant sludge

burning to get rid of water expensive

- leaves and other green collected from streets and parks
- bulky items (large appliances, hulks of old cars, tree limbs)

(MSW)= (refuse) + (C&D waste) + (sludge) + (leaves) + (bulky items)




Exercise No. 2 – Composition of MSW by identifiable items

- Make groups of 3-4 persons
- Grab a marker and a white board
- From the various categories of refuse and non refuse, which specific items would you say occupy more space in a landfill?
- **Hint**: we're talking about identifiable items now, break down *rubbish* into different sub-categories

Composition of MSW by identifiable items

Generation of MSW

Micro-Plastics: Macro Problem?

Although microbeads from rinse off cosmetics have received a lot of attention lately, the tiny plastics most often being found in our seafood is a different kind of synthetic. We look into marine life in the US and Australia, to find out what plastics escape our household drains and what kind of damage they can do. https://www.youtube.com/watch?v=UpGt5L3GC7o

Exercise No. 3 – MSW characteristics

- Make groups of 3-4 persons
- Grab a marker and a white board
- What should you measure?
- It depends on the planned use for the waste
- List down the possible end uses (or final destination) of MSW and what you would need to monitor as a solid waste engineer

MSW characteristics

What parameters to measure depends on the planned use for the MSW

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Have you heard of entropy?

Professor Brian Cox builds sandcastles in the Namib Desert to explain why time travels in one direction. It is a result of a phenomenon called entropy; a law of physics that tells us any system tends towards disorder.
https://www.youtube.com/watch?v=uQSoaiubuA0

Wonders of the Universe - BBC Two

Solid waste collection

Objective: To reduce entropy (increase order) in the system

- Disordered system: scattered MSW components
- Ordered system: all MSW components in a container and transported to a central facility or site

Examples of central facility or site:

- Materials recovery facility
- Disposal site e.g. landfill
- Transfer station

Disorder…

Image source: www.pixabay.com

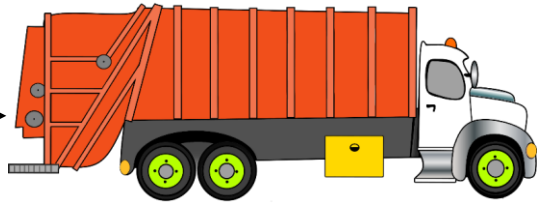
… to order

Image source: www.pixabay.com

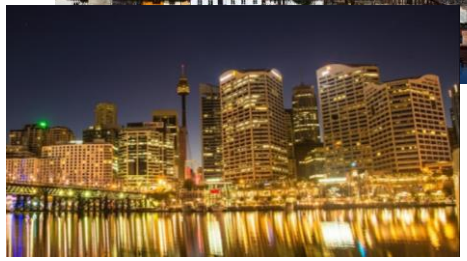
Solid waste collection: a multiphase process

Phase 1:
House-to-can

Phase 2:
Can-to-truck



Phase 3:
Truck from
house-to-house



Phase 4:
Truck routing

Phase 5:
Truck-to-disposal

Images source: www.pixabay.com

Phase 1: House-to-can

Images source: www.pixabay.com

Phase 1: House-to-can

- Regarded as a **personal affair** ⇒ received little attention
- Segregation of MSW viewed as an **inconvenience** by individuals

Three ways to set MSW collection fee		
Fixed tax system	***Volume-based fee system***	***Weight-based fee system***
• Pay a fixed amount regardless of amount of MSW • "Permission" to generate unlimited quantities of waste	• Pay according to volume of waste containers used • Generated interest in compactors usually	• Pay according to actual weight of MSW • Difficult to implement

Phase 2: Can-to-truck

Images source: www.pixabay.com

Phase 2:
Can-to-truck

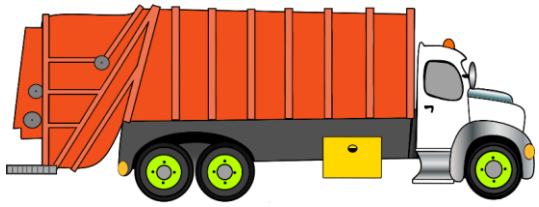
Who moves the can to the street?

- If collection crew, then *backyard collection*
- If waste generator, then *curbside collection*

Three ways to operate		
Manual collection	***Semi-automated collection***	***Fully-automated collection***
• Collectors empty cans into truck by hand • Requires a driver with many collectors	• Utilizes can-on-wheels • Collectors move cans close to hydraulic hoists on truck, which empties the can into truck • Requires a driver with a couple of collectors	• Truck equipped with long arms that reach out, grab a can, and empty can into back of truck • Requires only driver

Figure 3-7 Collection with vehicles equipped with "can snatchers."

Phase 3: Truck from house-to-house



Phase 3:
Truck from
house-to-house

Images source: www.pixabay.com

Compaction ratio is important

- Higher ratio = More efficient collection

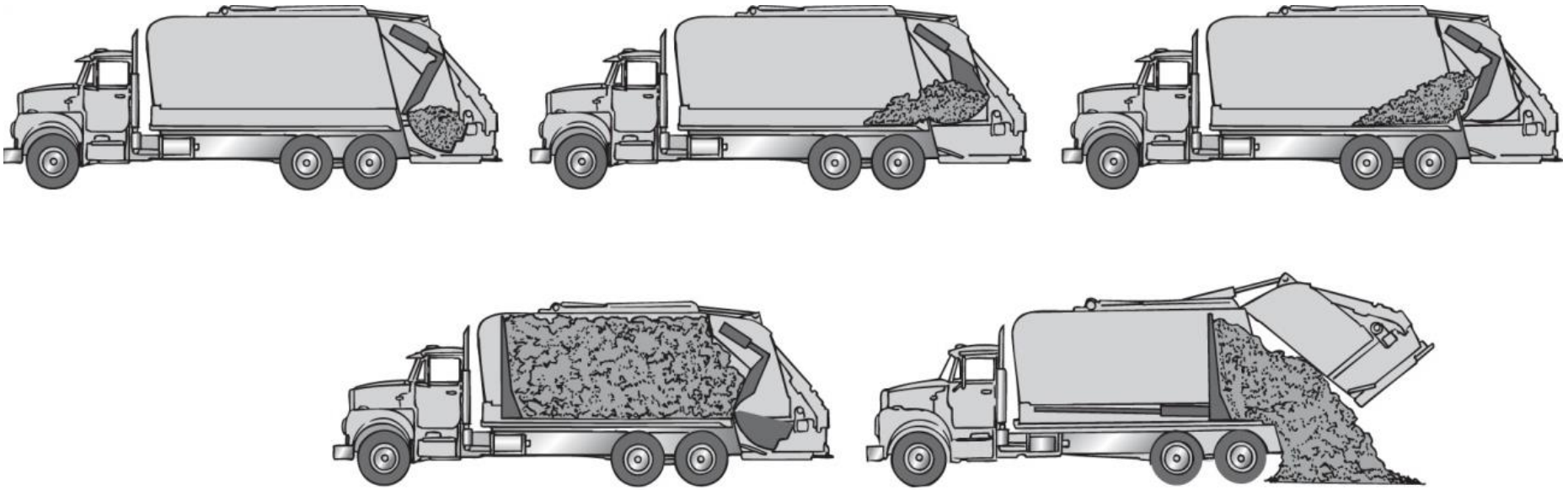
Crew size: Backyard pickup > Curbside pickup

Max capacity of one truck before landfilling is required:

- In theory: 700-1000 customers
- In practice: Only about 200 customers

Phase 3: Truck from house-to-house

Compacting mechanism for a packer truck



Phases 4 and 5: Truck routing and truck-to-disposal

Phase 4: Truck routing

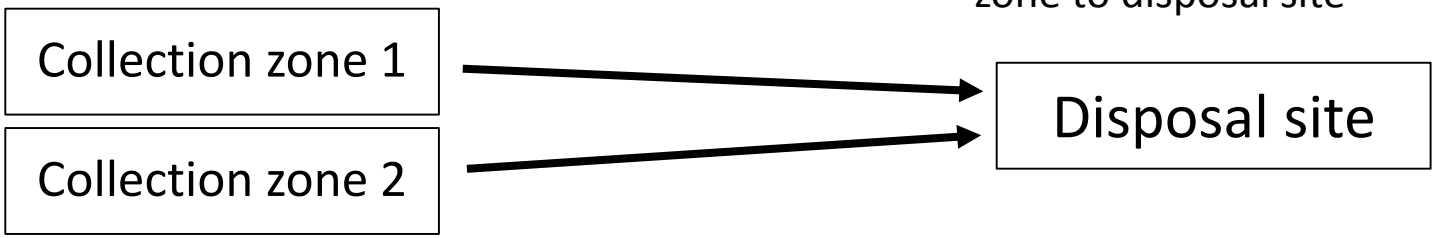
Microrouting

Routing inside an assigned collection zone

Phase 5: Truck-to-disposal

Macrorouting

Routing from collection zone to disposal site



Phase 4: Truck routing

Microrouting

Objective: design routes within collection zone that minimize deadhead (travelling without picking up waste)

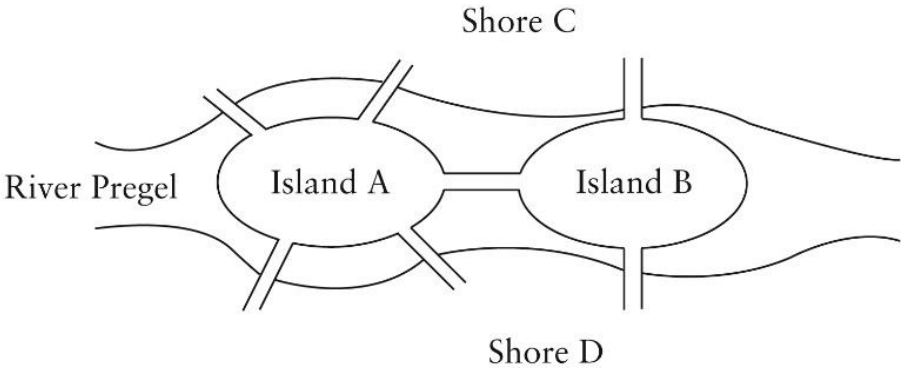
Follows heuristic (commensensical) principles

- *Routes*: no overlaps, no fragmentation
- *Starting point*: closest to the truck garage
- *Heavily travelled streets*: avoid during rush hours
- *One-way streets*: lopped from the upper end
- *Dead-end streets*: collect on the right side

Euler's tour

Prussia's King problem: to route a parade across seven bridges of Königsberg **without crossing the same bridge twice**

Euler's problem in Königsberg



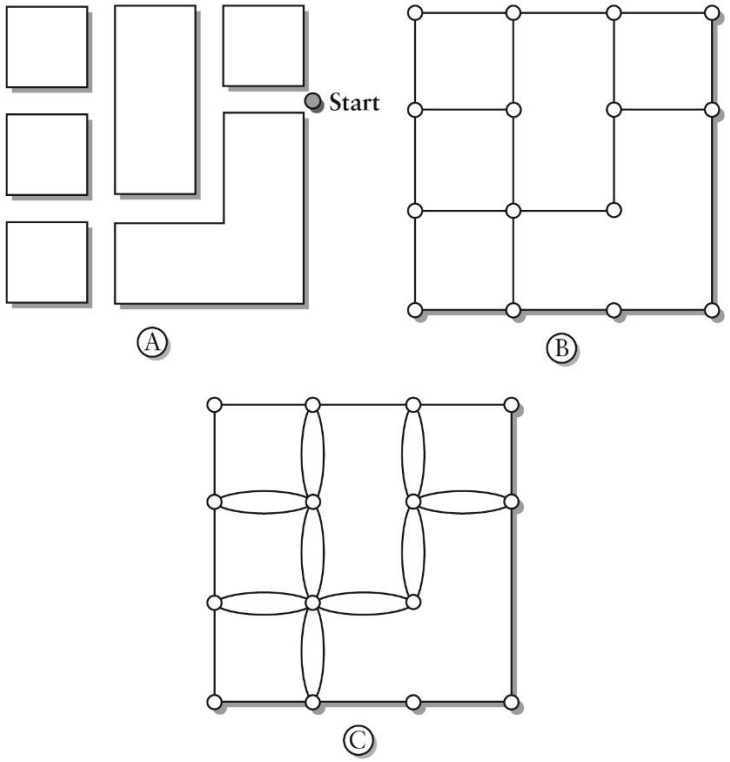
Exercise No. 4 – Euler's tour

Are these possible?

Scenario A: By traveling down each street only once (MSW collected along both sides of street, e.g., residential neighborhood)

Scenario B: Collection only on one side of the street at a time (larger street)

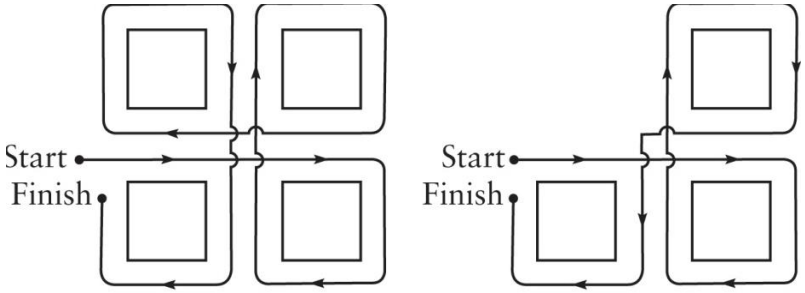
Routing of trucks



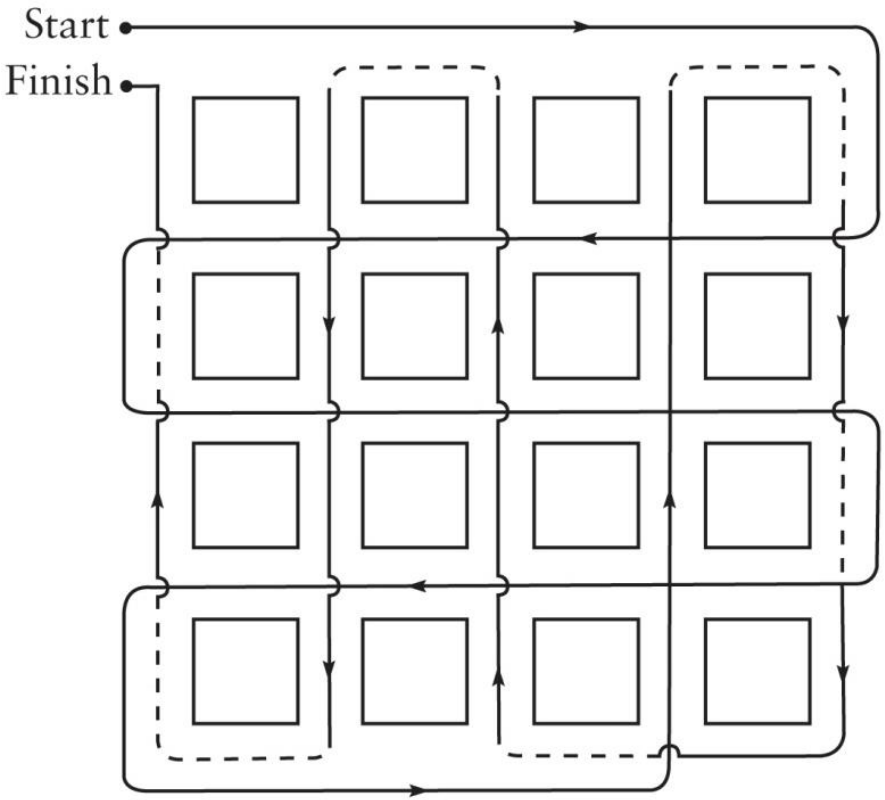
Euler's tour

Larger loops usually result in more efficient collection

Small loop:



Large loop:



Phase 5: Truck-to-disposal

Macrorouting

Objective: determine the most direct route from collection zone to disposal site

small community: finding the most direct road (end of the route to disposal site)

metropolitan areas and regional systems: optimum transport and disposal scheme

Phase 5: Truck-to-disposal

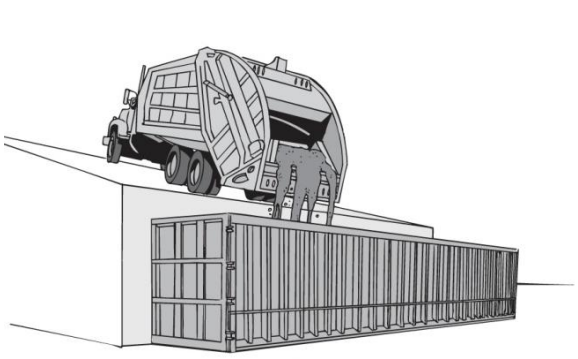
Macrorouting

Objective: determine the most direct route from collection zone to disposal site

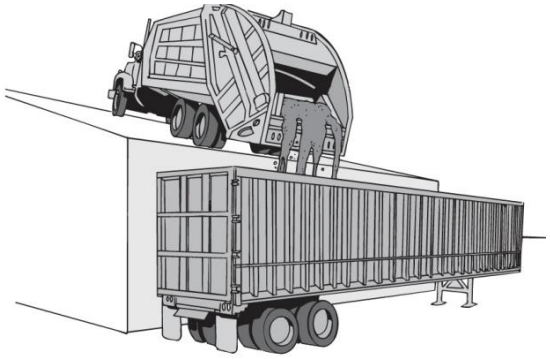
small community: finding the most direct road (end of the route to disposal site)

metropolitan areas and regional systems: optimum transport and disposal scheme

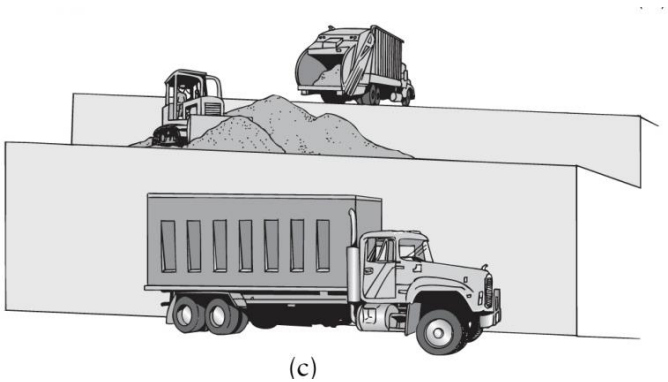
There could be a need for a *transfer station* depending on the haul distance to disposal



(a)



(b)

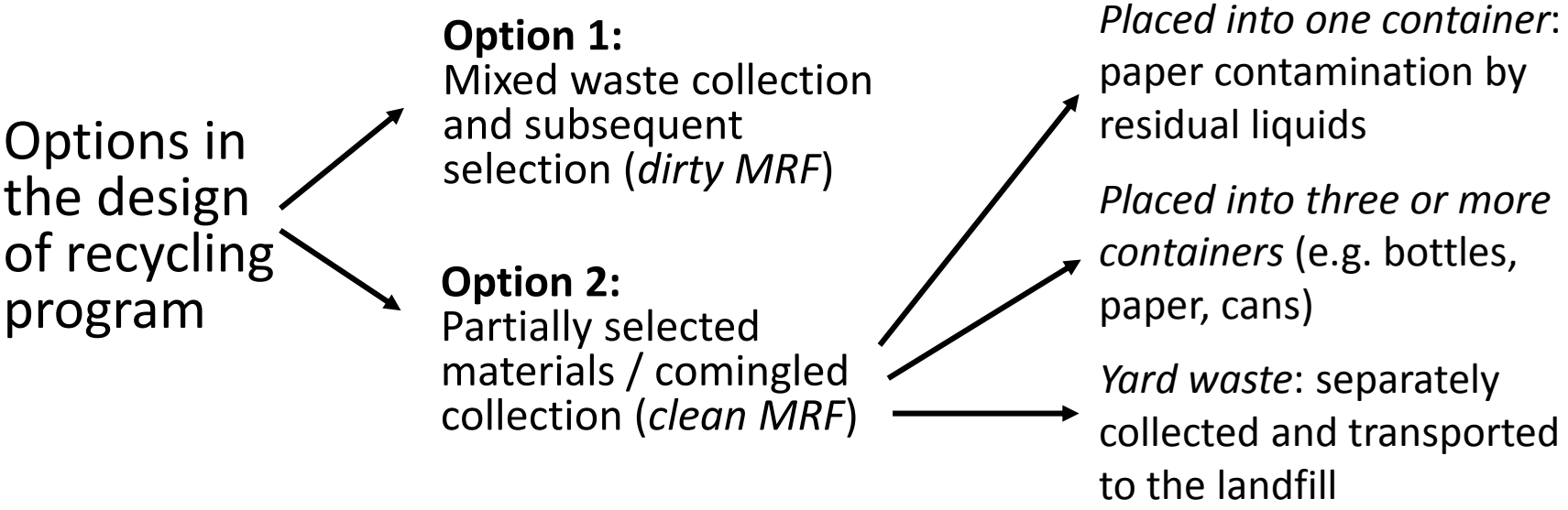


(c)

Recycling

Entered the mainstream of solid waste management in 1990s

- Could be profitable, regardless of the price of recycled materials
- Requires government leadership and public acceptance that recycling is not free



Profitability of recyclables: Aluminum

By some measures, the most valuable collectable in any municipal recycling program

- 10× more valuable than plastics (PET, HDPE)
- 20× more valuable than glass or newspapers
- 20-40% of the total revenues from recycling

Uses 2-3% of the energy required to make new aluminum from bauxite ore

Al(OH)3

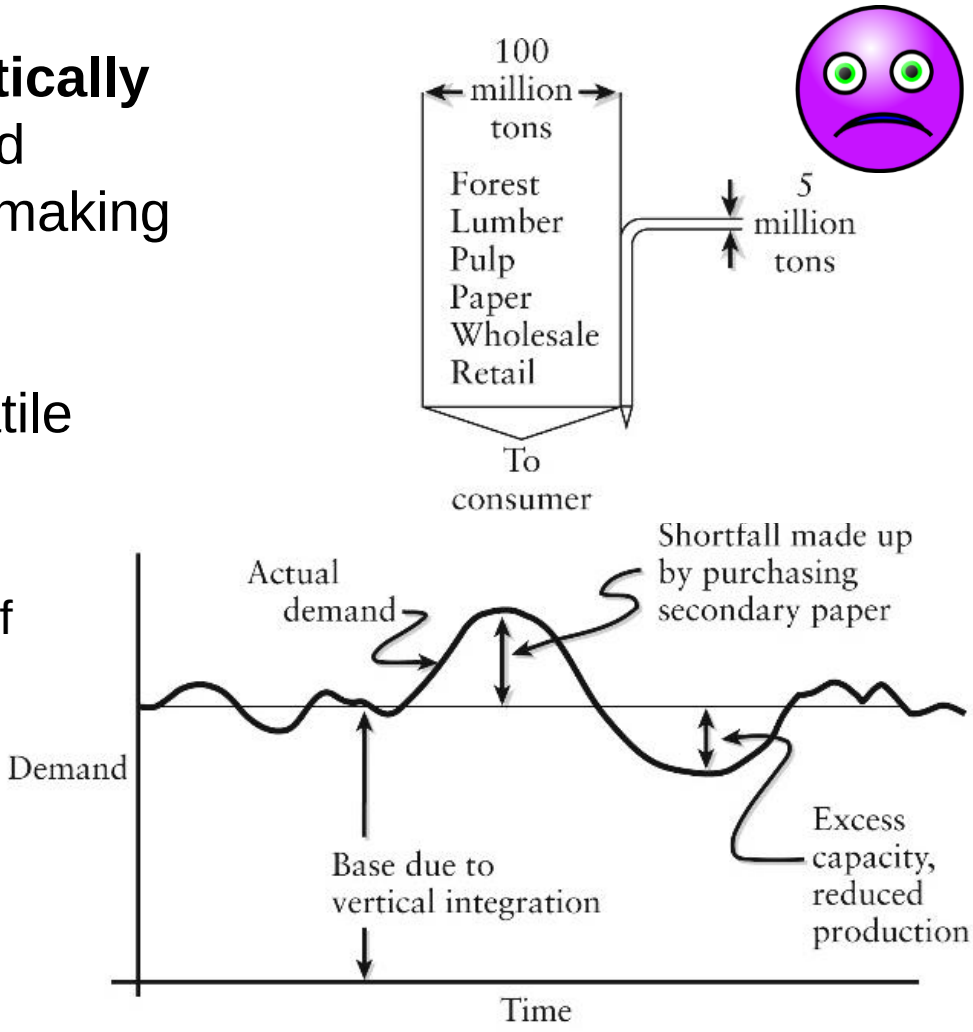
Source	Electricity (kWh/kg)	Fossil fuel (kJ/kg)	Primary energy (kJ/kg)
Bauxite	15	60,000	220,600
Recycled aluminum	0.08	4200	5060
Recycled savings	14.92	55,800	215,540
Percent savings	99%	93%	98%

Profitability of recyclables: Paper

Paper industry companies are **vertically integrated**: the company owns and operates all the steps in the papermaking process

Market for secondary paper is volatile

- Low capacity drives short-term increase in demand for recycled paper, leading to spikes in price of recycled paper
- When paper companies have expanded their capacity, price of recycled paper plummet



Exercise No. 5 – Practice Exam No. 1

- Make groups of 3-4 persons