Chapter 16

Waste Generation and Waste Disposal

Paper or Styrofoam; Which is Better?!?!?

Use Textbook pg. 437 (472 on-line version) to help you decide and support your claim.

Think environmentally, ecologically, economically and socially.

Paper vs. Styrofoam

(Life-cycle Analysis)

Pro:

- Decomposes (landfill – produce of methane gas)
- Uses renewable material
- Could be recycled or composted

Con:

- Cannot hold without cardboard band for hot liquids (environmental conseq.- **more waste**)
- Uses 2x as much energy, more water to make
- Heavier, requires more energy to transport (air pollution)
- Used once, throw away
- Bleach used to make, may cause harm to aquatic life (disposal process)
- Small amt. of energy yield (incineration – air pollution)

Pro:

- Minimizes temp. changes
- Lighter, insulates better, less expensive
- Potentially capable of using more than once (typically used once)

Con:

- Does not decompose (landfill)
- Uses non-renewable material
- Polystyrene cup might leach chemicals from plastic material to hot liquid (health risk – social conseq)
- Small amt. of energy yield (incineration – air pollution)
- Workers exposed to toxic emissions

Inputs vs. Outputs vs. Internal Changes in an Ecological System

- In an Ecological System, *plant material, nutrients, water, & energy* are the **INPUTS** (Human inputs are similar but can be manufactured goods as well)
- **OUTPUTS** include *anything not useful or consumed, and non-useful products* are called **Waste**
  - **Waste is a component of a human-dominated system in which the products are manufactured, used, and eventually disposed of** (waste of one system may the input of the next system Ex. fertilizer)

Since the early 1950's with the upcoming of paper & plastic products (disposal diapers) we are known as the ***"throw-away society"*** ….referred to as ***planned obsolescence*** **–** *goods become obsolete and require replacing*

Municipal Solid Waste (MSW)

~Waste collected by municipalities from households, small businesses, and institutions such as schools, prisons, municipal buildings & hospitals.

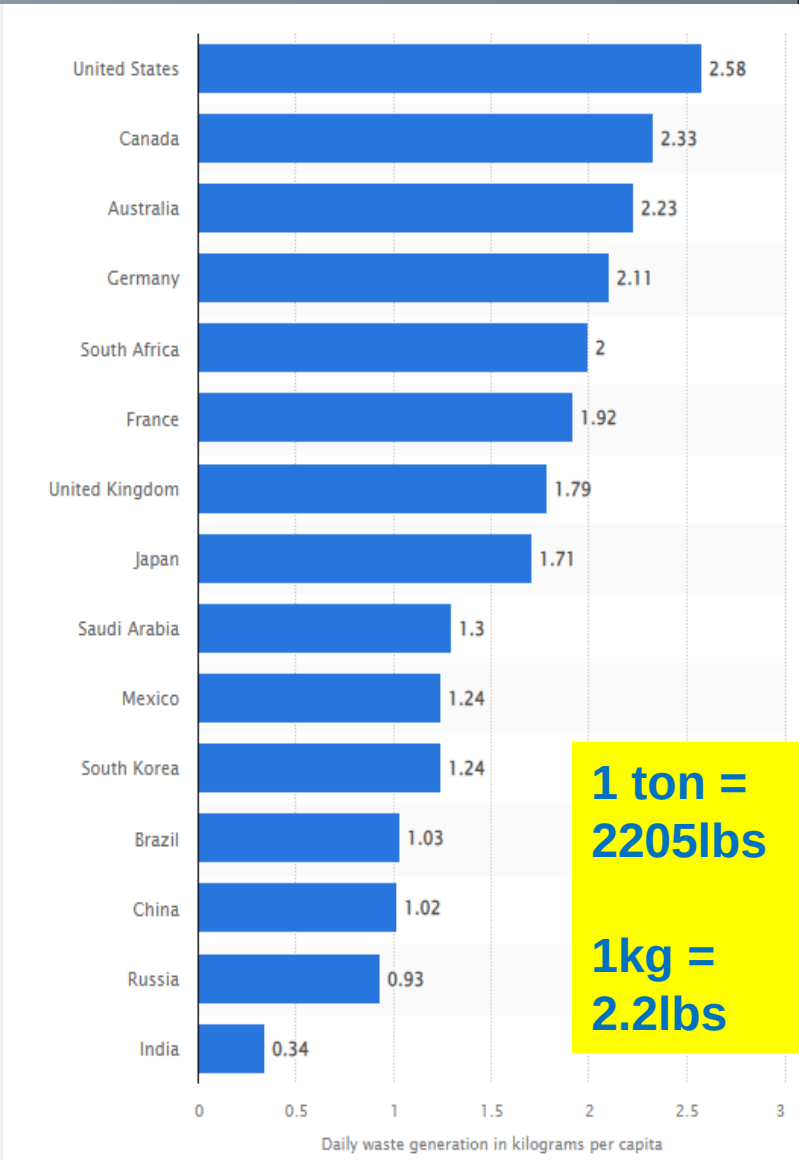
- EPA estimates 55-65% of MSW comes from residents (ex. Flushable wipes) and 35-45% from commercial & institutional facilities

~Waste management is entails **handling solid garbage and getting rid of undesirable goods and chemicals in a secure and effective way.**

~Solid, liquid, and gaseous waste is all included in waste management. **Municipal, industrial, and hazardous** garbage are all dealt with via waste management.

~ Waste produced during production and manufacturing operations in industries is referred to as **industrial waste.**

MSW generated per capita worldwide in kg (2019)

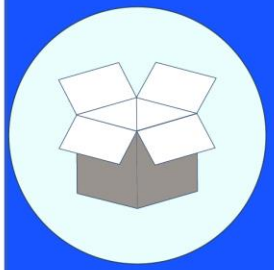
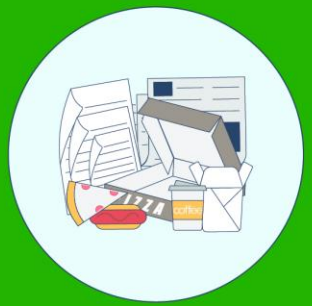


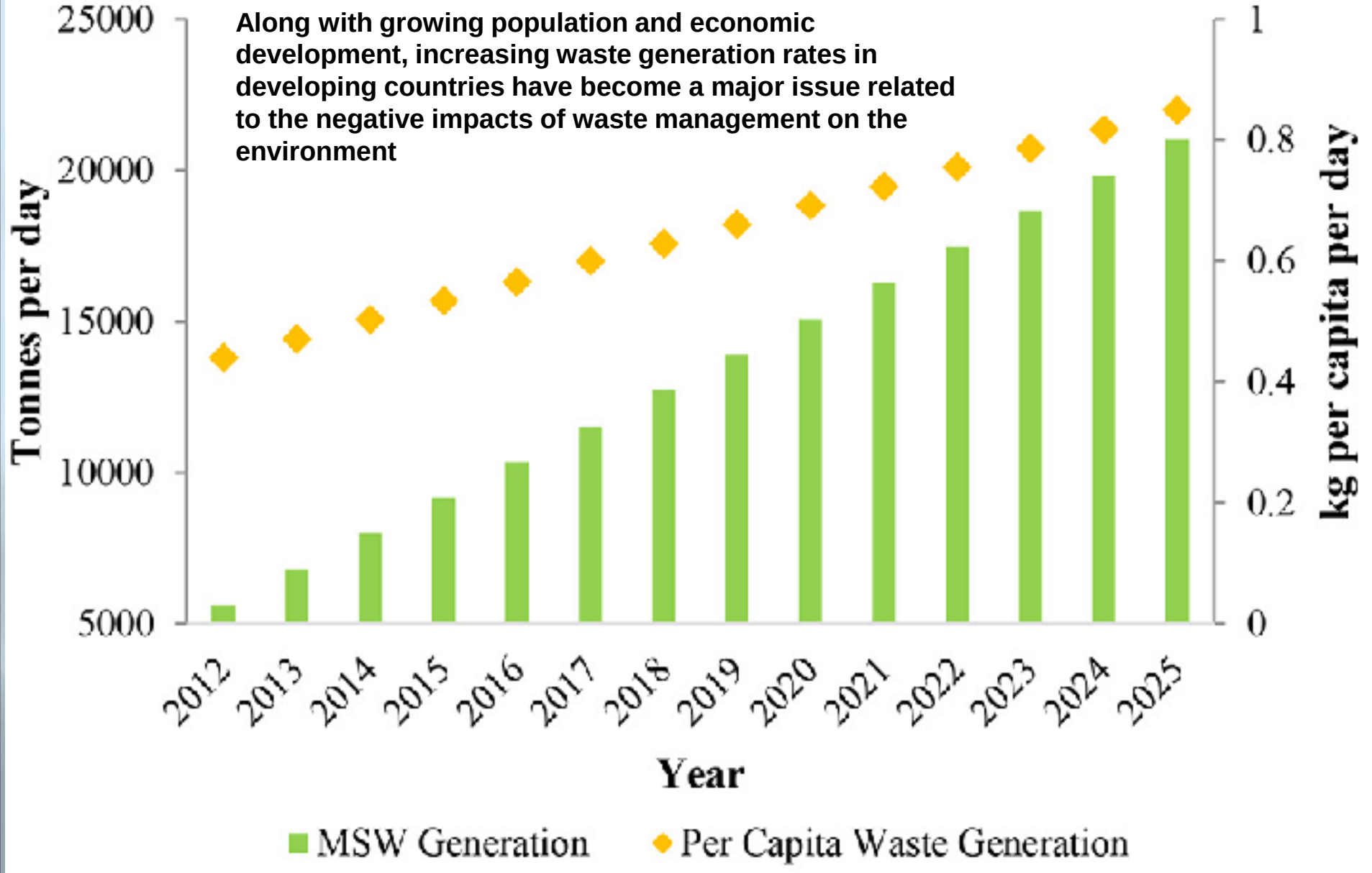
1 ton = 2205lbs

1kg = 2.2lbs

Waste Stream- the flow of solid waste that is recycled, incinerated, composted or placed in landfill (or disposed in a different way).

#ACKLocal

RECYCLABLE WASTE				COMPOSTABLE WASTE	NON-RECYCLABLE NON-COMPOSTABLE WASTE
Shipping Boxes Cajas de embalar	Plastics Plástico	Tin/Aluminum Lata/Aluminio	Glass Vidrio	Desechos biodegradables	Desechos No biodegradables No reciclables
					
Clean corrugated cardboard. Empty and flatten.	Bottles, cups, jars, jugs and tubs. Empty, rinse and replace cap.	Cans, aluminum, foil items, lids and bottle caps. Empty and rinse. **Metal aerosol cans should go in the metal bin.*	Bottles and jars. Empty and rinse. **Window or drinking glass belongs in non-recyclable non-compostable waste.*	Food scraps and mixed paper. All food waste, pizza boxes, cracker and cereal boxes, paper towels, paper bags, newspapers, magazines, tissues, coffee grounds, cooking oil/grease, pet waste. **Can be delivered in a clear plastic bag. Paper bag preferred.*	Non-recyclable and non-compostable waste. Plastic bags, styrofoam, plastic wrappers, cleaning wipes, diapers, incandescent lights, milk cartons, chip bags, products made from a mix of materials.

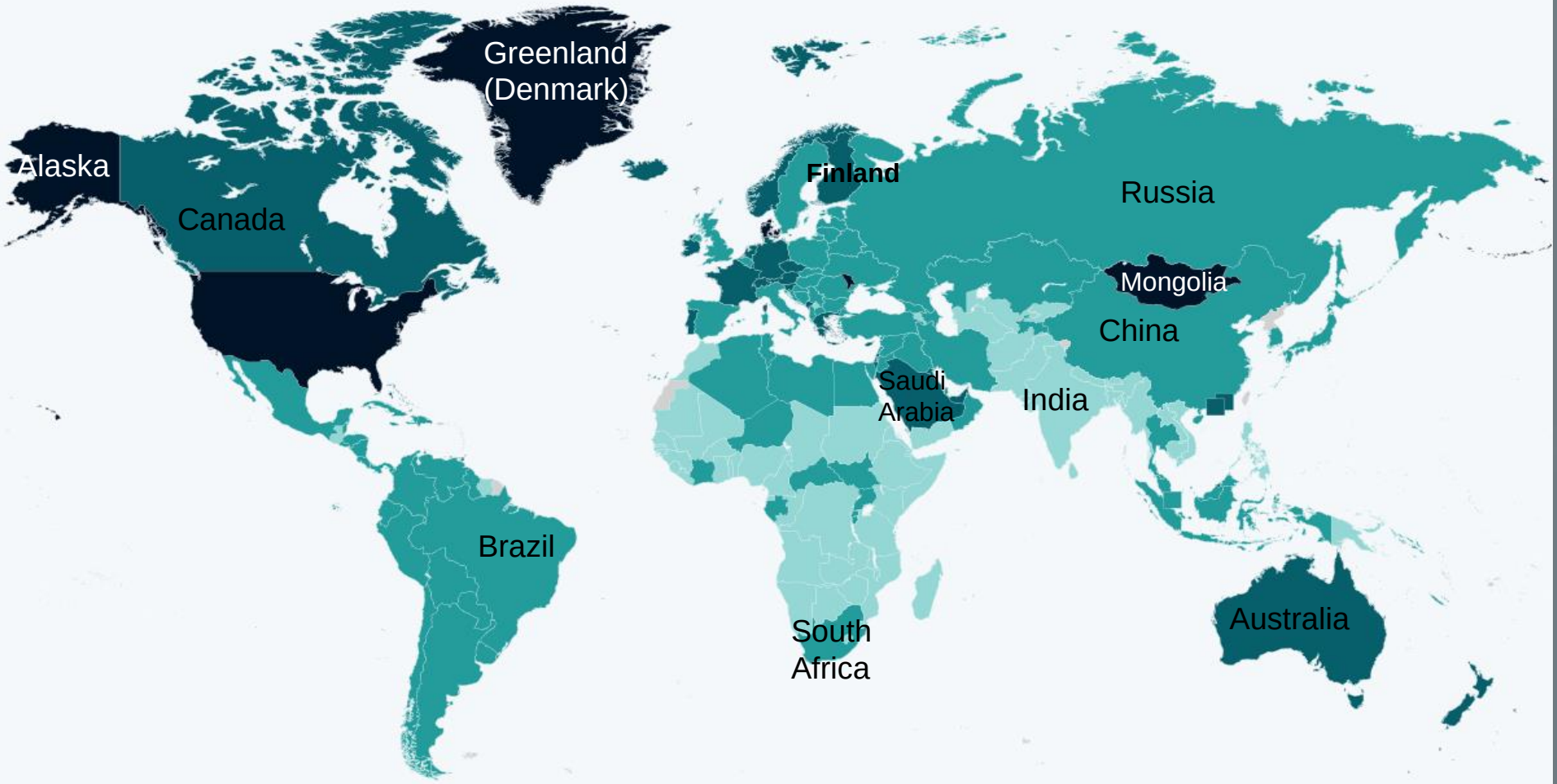


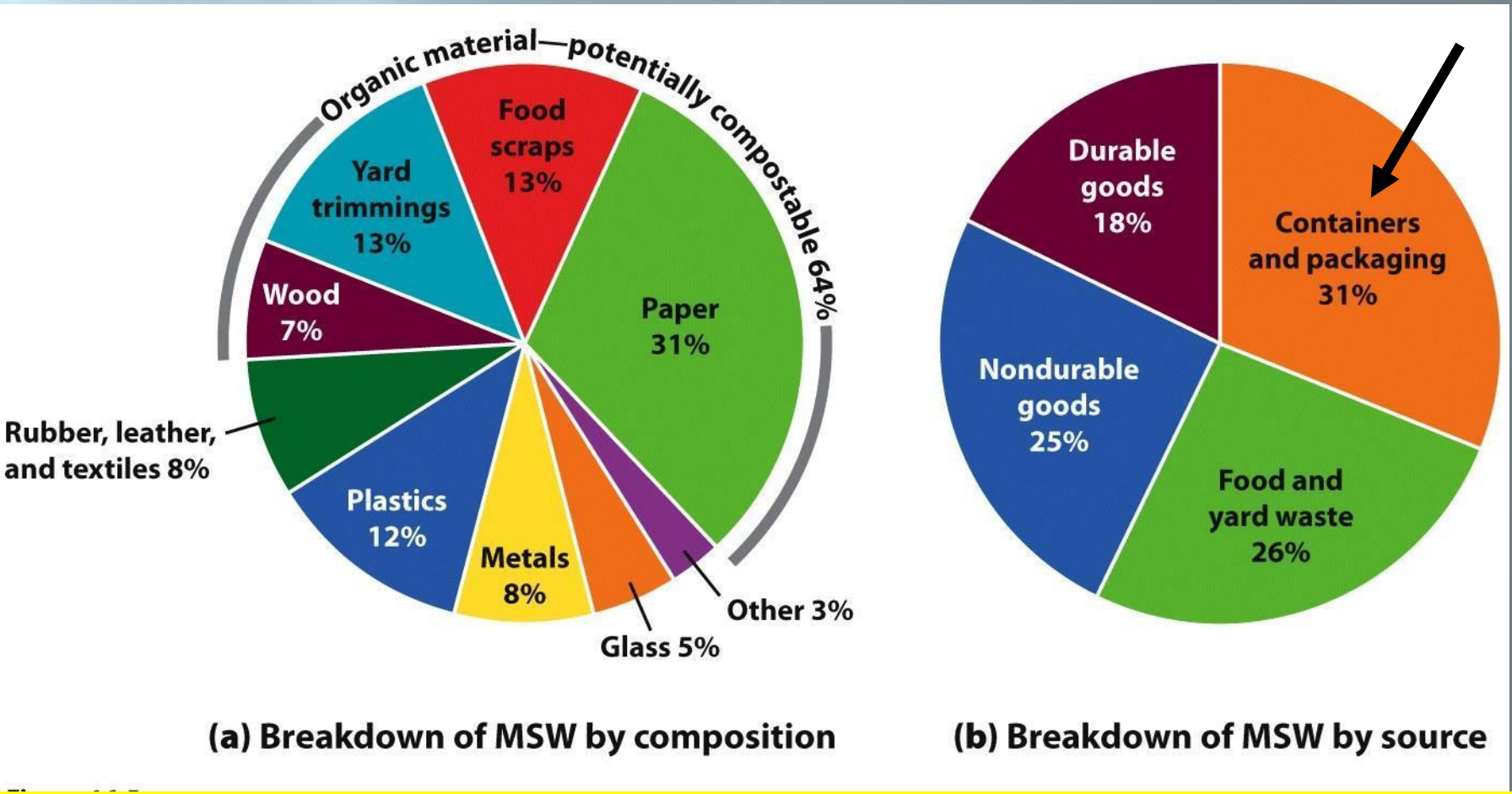
Solid waste generation and per capita waste generation

A World of Waste

Municipal solid waste generated per year (in kilograms per capita)

Less than 200 kg | 200-499 kg | 500-799 kg | 800-1,100 kg

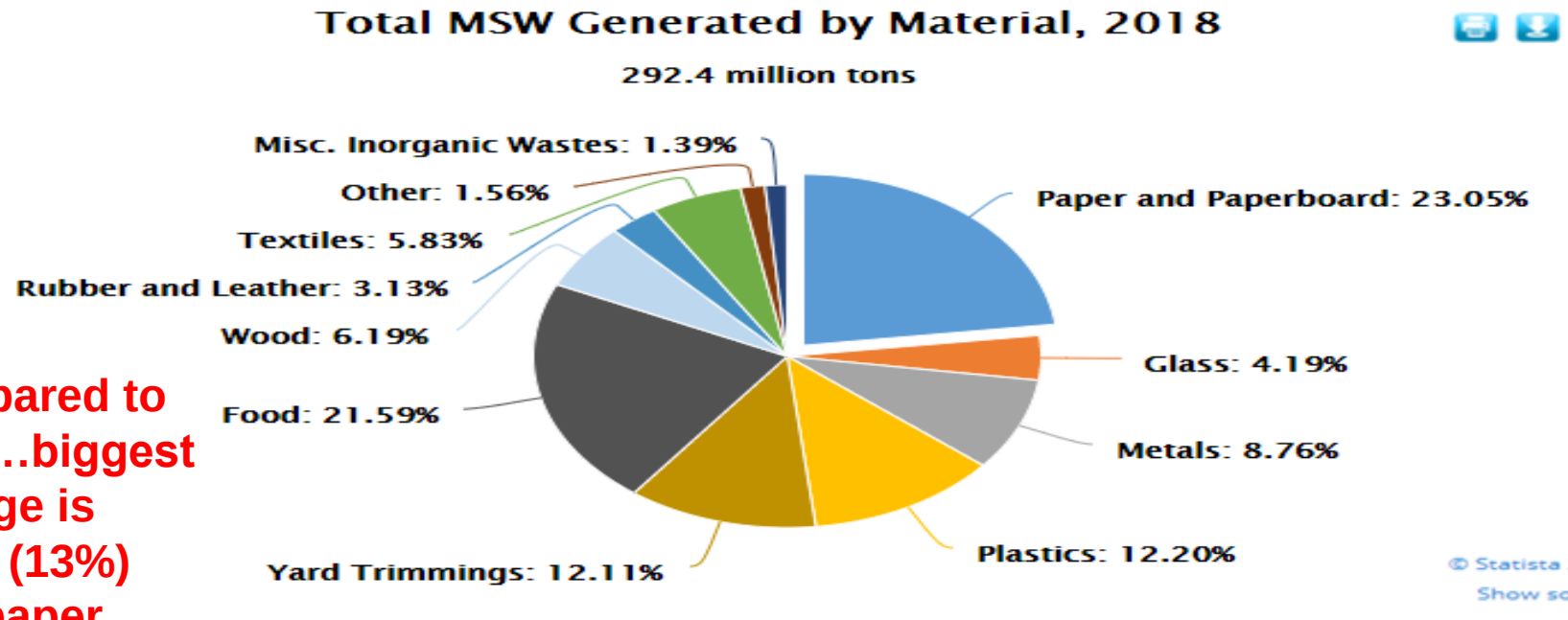




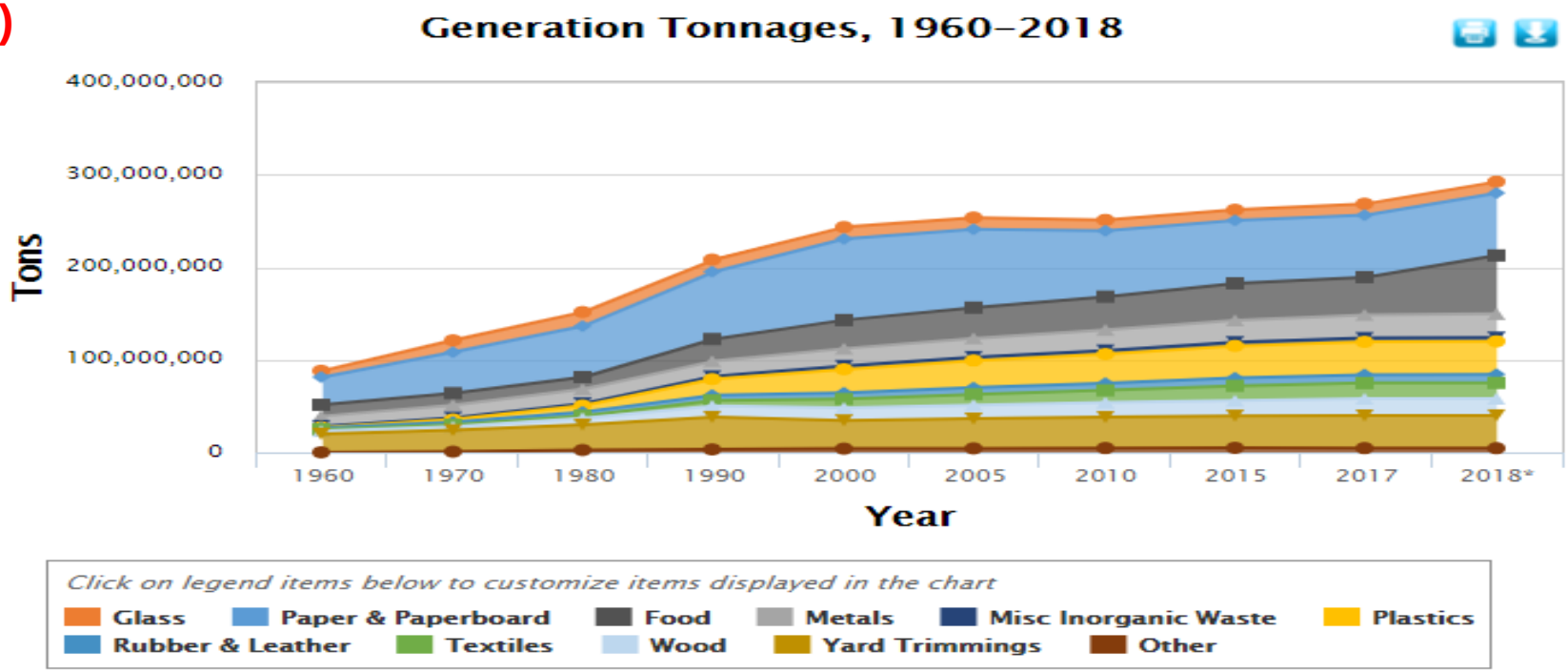
Composition of Municipal Solid Waste in 2012

Waste generation varies by season of the year, socioeconomic (more $$, more waste), geographic location with the country.

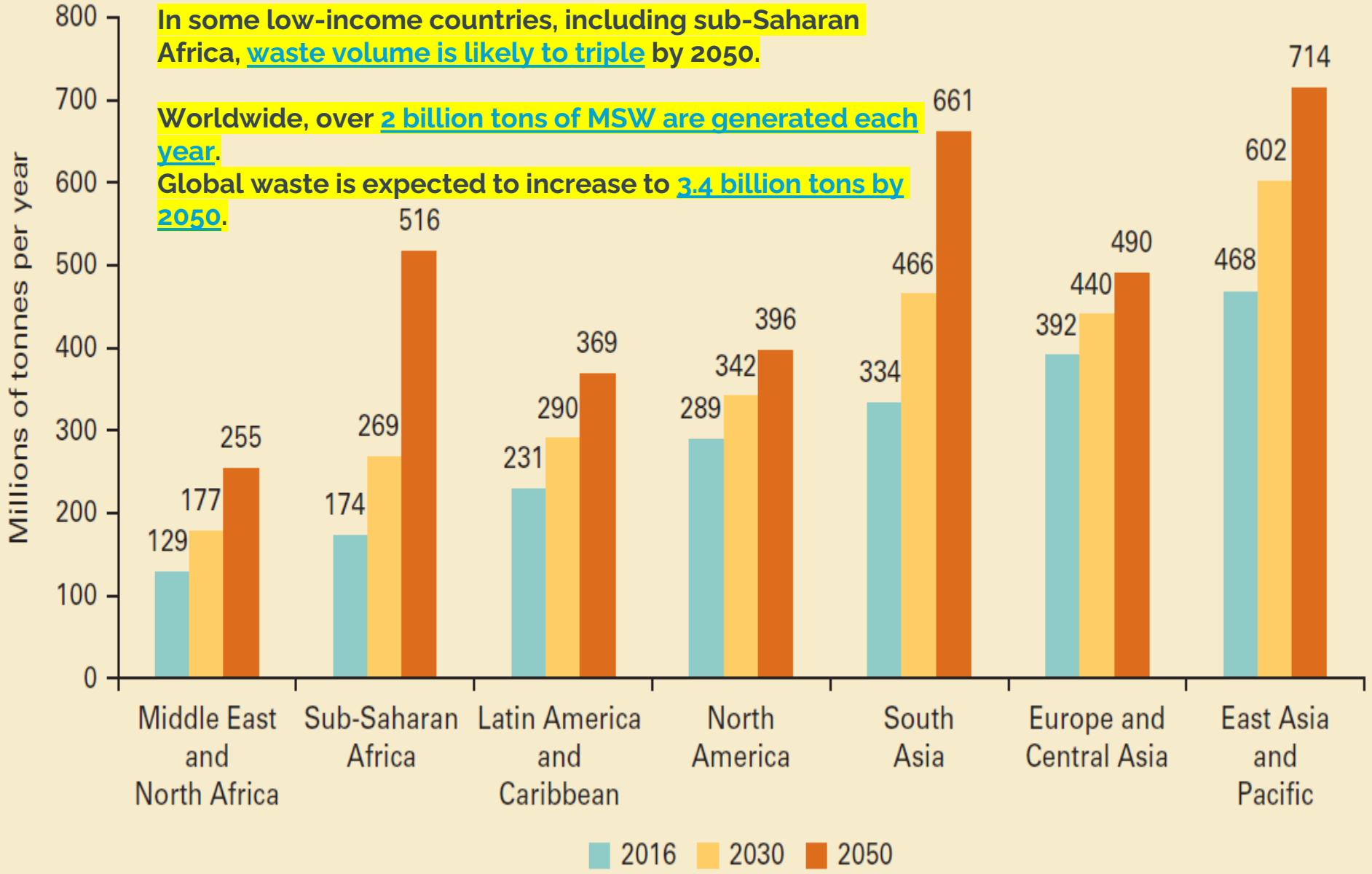
Agricultural waste, mining waste, industrial waste average 4.5 - 5lbs/person in U.S, developed nations range from 1.8 - 4.8lbs/person, (*Japan 2.4 - 3lbs/person)



Compared to 2012…biggest change is Food (13%) and paper (31%)



Projected waste generation, by region (millions of tonnes/year)



The Enormous Scale of Global Food Waste

Total annual household food waste produced in selected countries*

China accounts for 15.55% of all global municipal solid waste generation.

Total food waste per year (tonnes)
Estimated food waste per capita (kg)

	Total food waste per year (tonnes)	Estimated food waste per capita (kg)
China	91,646,213	64
India	68,760,163	50
United States	19,359,951	59
Japan	8,159,891	64
Germany	6,263,775	75
France	5,522,358	85
United Kingdom	5,199,825	77
Russia	4,868,564	33
Spain	3,613,954	77
Australia	2,563,110	102

As of 2020, private US households waste around 43% of all food….translates to annual financial loss of $1500 (family of four). Average American produces about 5 pounds of trash per day. Families produce about 18 pounds.

Over 40 mil tons of food ends up in landfill every year, equating to more than $161 billion.

* UNEP estimates with high or medium confidence
Source: UNEP Food Waste Index Report 2021

Approximately 200 billion pounds of food waste per year in America.

Forbes statista

HERE'S HOW MUCH THE AVERAGE AMERICAN WASTES EACH MONTH

283 KW HOURS OF ENERGY → That's like an electric oven running at 350°F for 6 full days.

551 POUNDS OF RECYCLABLES → That's about 28.5 reams of office paper.

1,048 POUNDS OF TRASH → That's roughly the weight of a grand piano.

2,500 GALLONS OF WATER → That's equal to 83 baths.

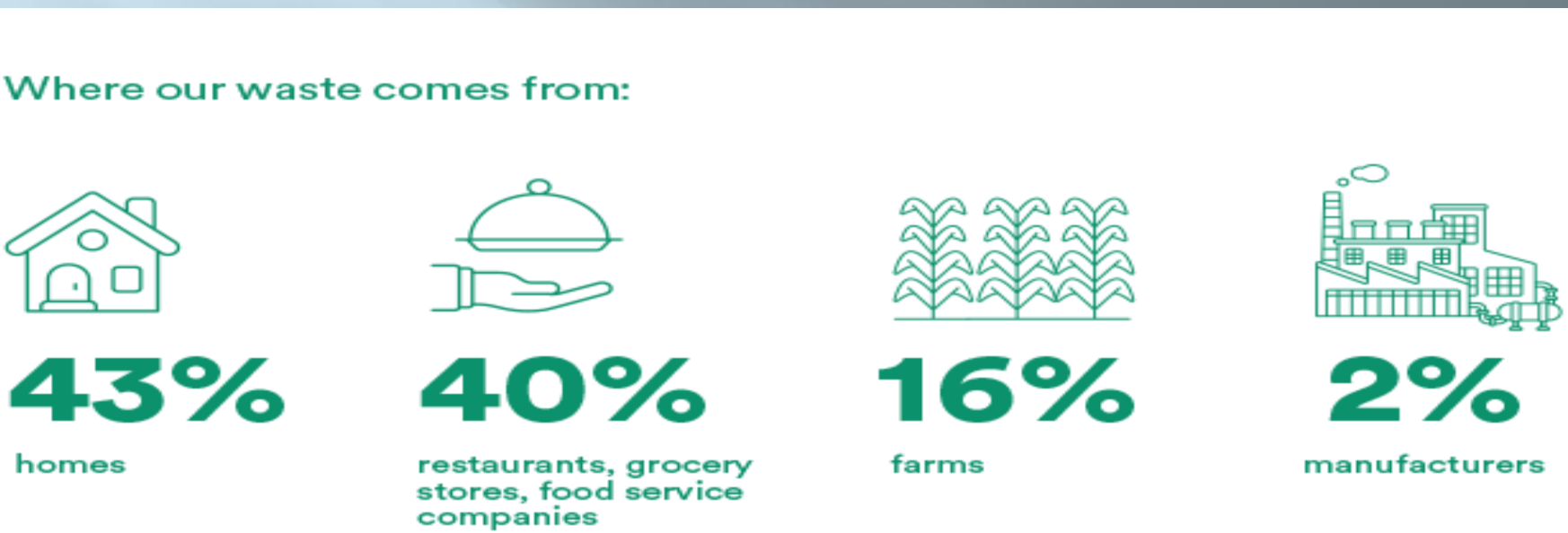
37,470 CALORIES OF FOOD → That could feed another person for 19 days.

NOTE: These estimates are subjective and vary widely with location, distribution methods and individual choices.

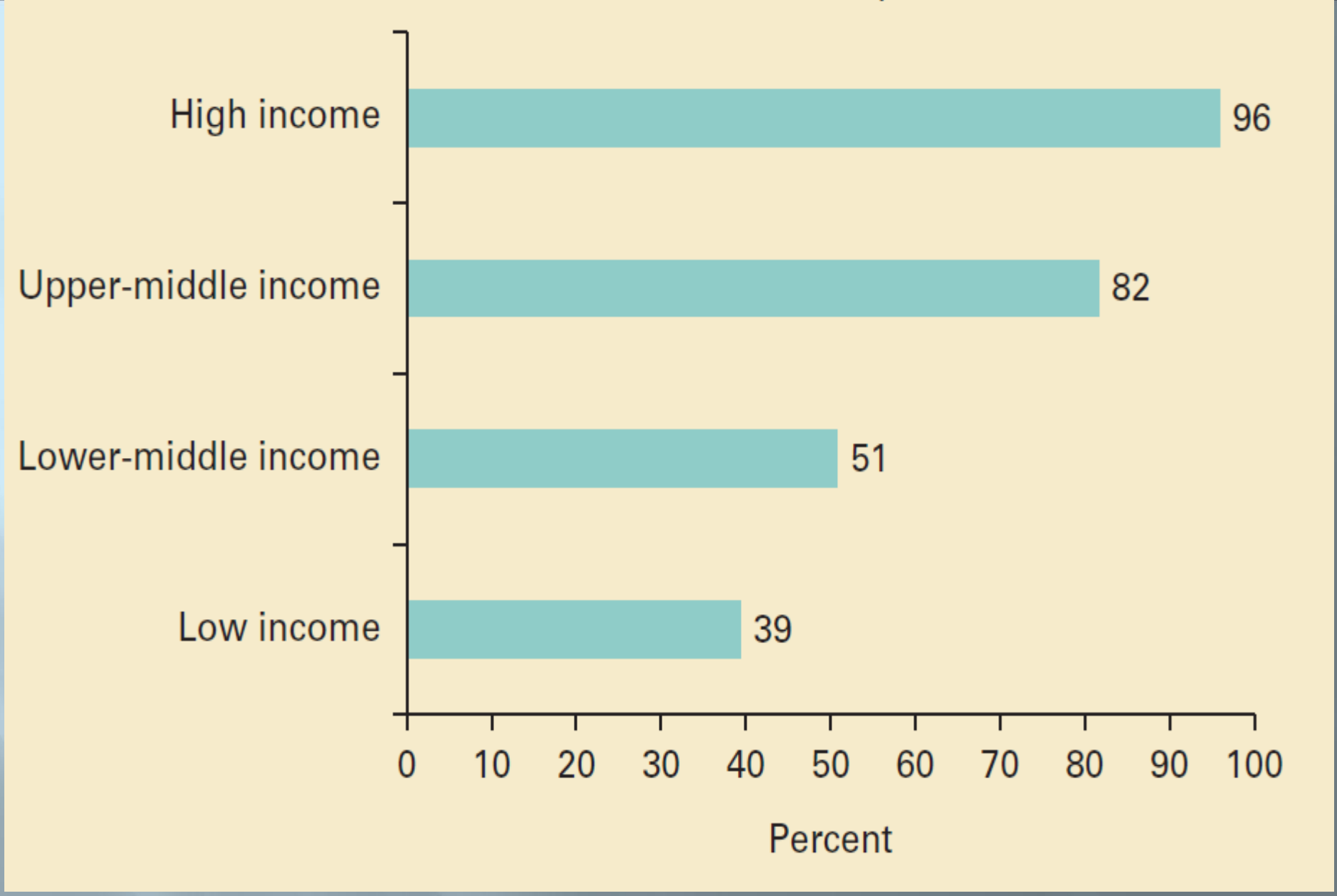
SOURCES: NPR; EPA; The Washington Post; Opower blog; California Energy Commission

TECH INSIDER

The root is complex and multifaceted, with waste coming first from America's….



Wasting food contributes to 11% of the world's greenhouse gas emissions.



Waste composition differs across income levels, reflecting varied patterns of consumption. High-income countries generate relatively less food and green waste, at 32% of total waste, and generate more dry waste that could be recycled, including plastic, paper, cardboard, metal, and glass, which account for 51% of waste.

Global food losses and waste per year

around **1/3** of the world's food is squandered, that is

1.3 billion tons of wasted food at

1 approx. trillion USD costs

US Creates 3x the Global Average of Waste

IFCO

- **45%** of all **fruit and vegetables**
- **35%** of all **fish and seafood**
- **30%** of all **cereals**
- **20%** of all **dairy products**
- **20%** of all **meat and poultry**

China and India combine to make up more than 36% of the world's population. Create 27% of the world's municipal waste, Americans 2x amt.

upply chain serves us all. **Let's eat.**

2.5 bn tons

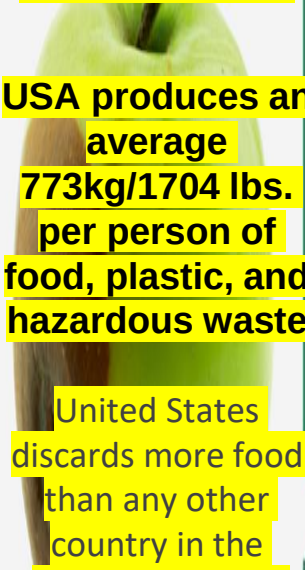
Amount of produced food lost or wasted globally every year.

45%

Percentage of all fruits and vegetables not eaten globally every year.

1 ton = 2200lbs

1kg = 2.2lbs



USA produces an average 773kg/1704 lbs. per person of food, plastic, and hazardous waste

United States discards more food than any other country in the world: **nearly 60 million tons — 120 billion pounds — every year.**

The world wastes about 2.5 billion tons of food every year

~ $940 billion annually food lost or wasted

Market value of food lost globally every year.

10%

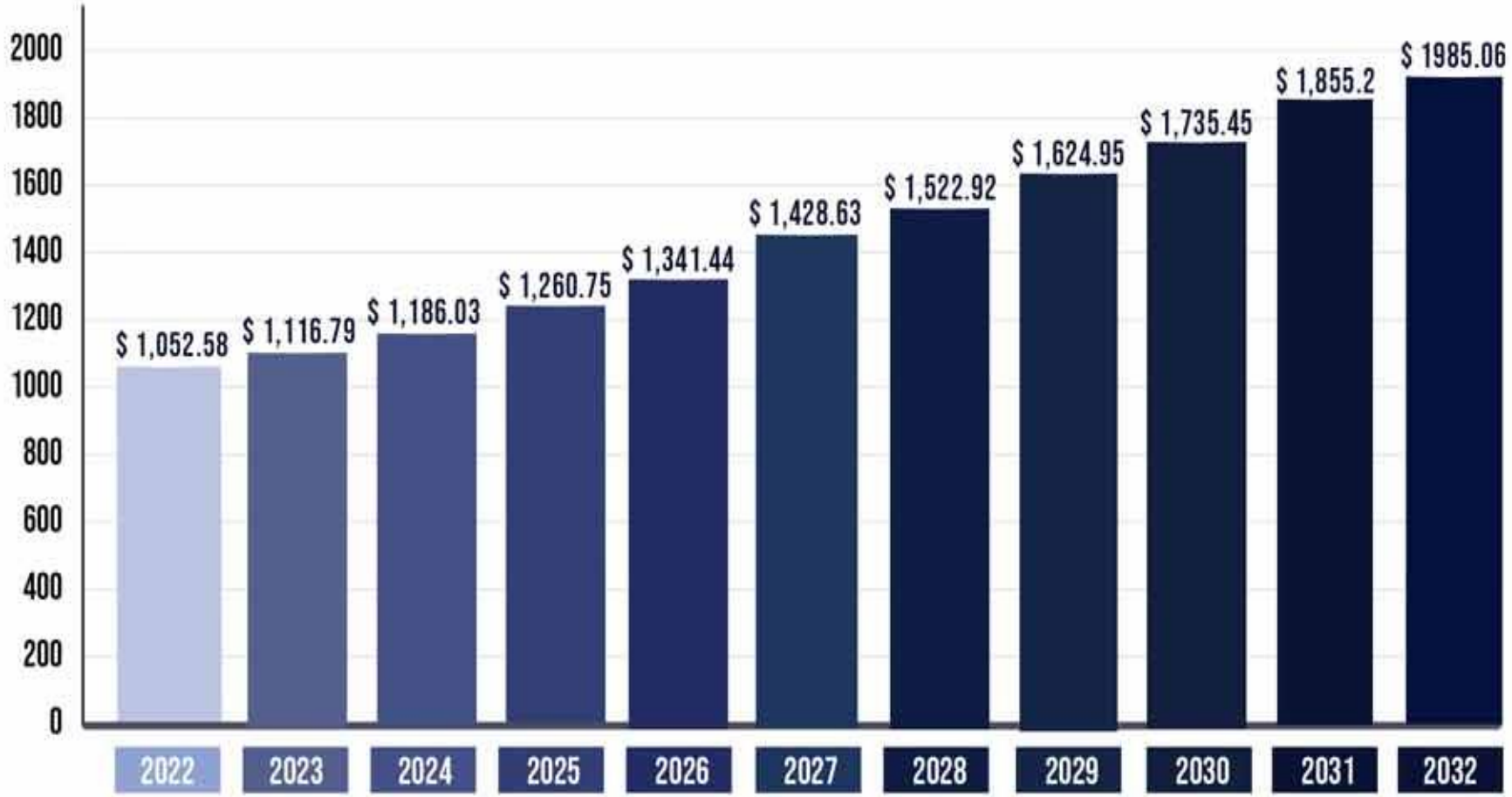
Percentage of greenhouse gas emissions caused by food loss.

In **Australia** and **New Zealand** 5-6% of all **food is lost along the supply chain.**
In **Central** and **Southern Asia,** that figure shoots up to 20-21%.
In **Europe** and **North America** food loss adds up to around 16%. 7x higher than Ethiopia, which produces the world's least amount of waste.

In developing countries, occurs at early stages due to limitations in harvesting technique, storage and transportation infrastructure

PRECEDENCE RESEARCH

WASTE MANAGEMENT MARKET SIZE 2022 TO 2032 (USD BILLION)

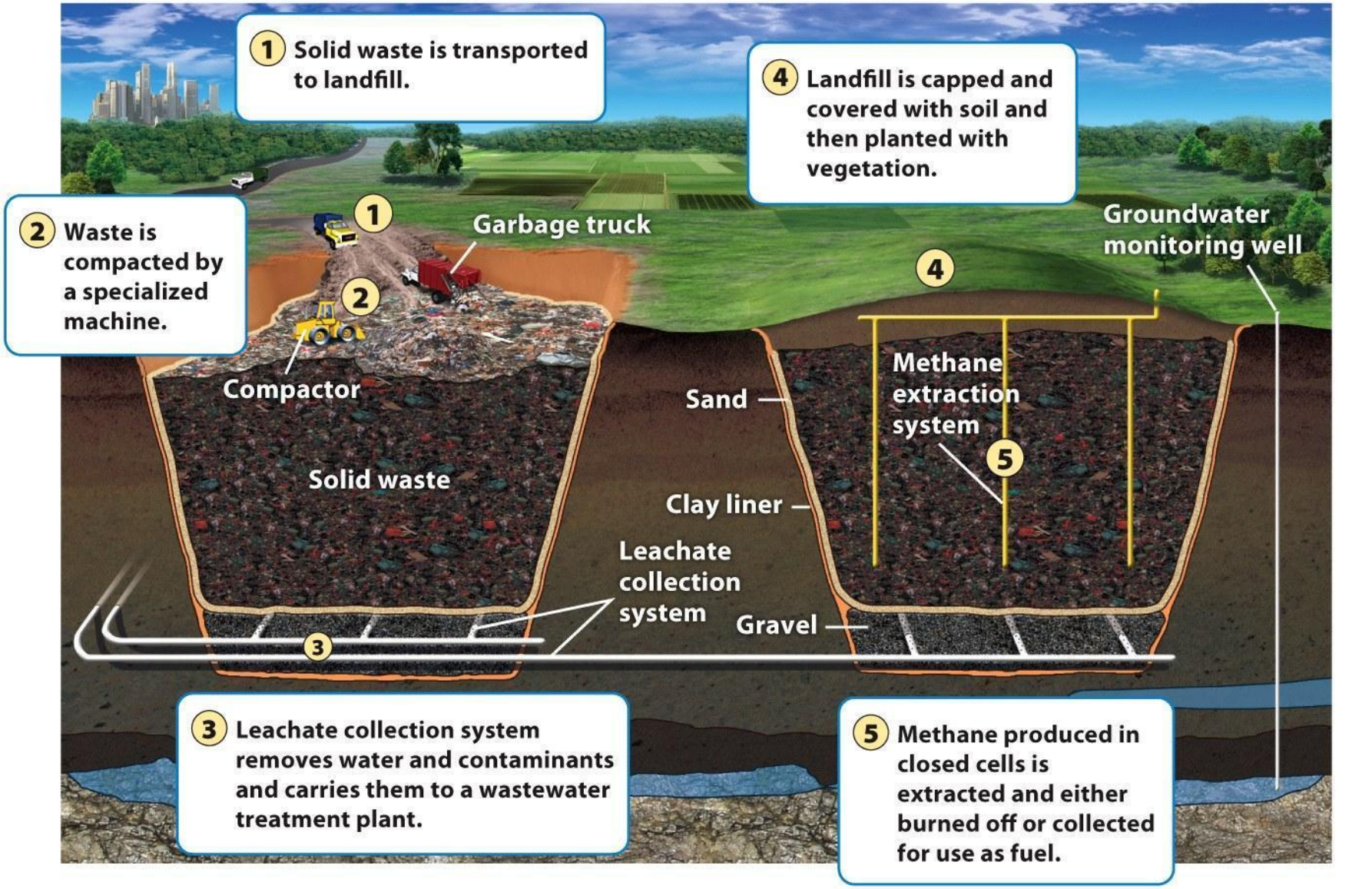


Source: www.precedenceresearch.com

The global waste management market size was estimated at $1052.58 billion in 2022 and is expected to hit around $1985.06 billion by 2032, poised to grow at a compound annual growth rate (CAGR) of 6.60% from 2023 to 2032.

1. Landfills

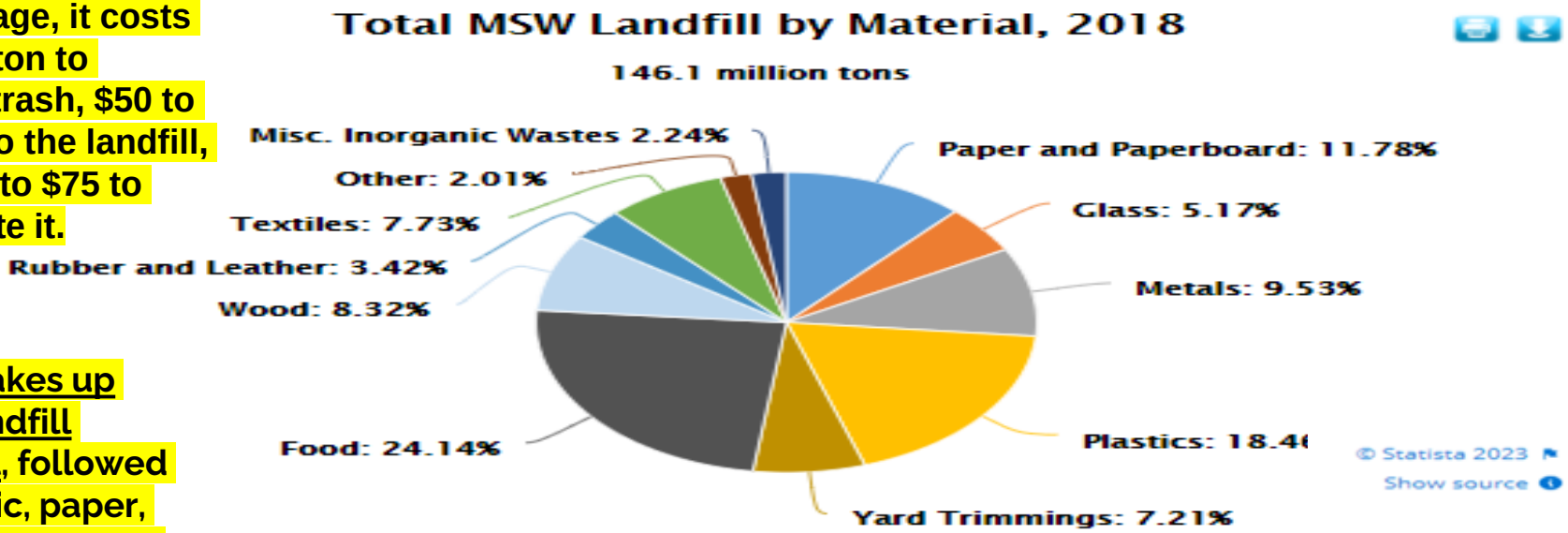
- **Sanitary landfills-** engineered ground facilities (holes lined with clay (**impede water flow**) designed to hold MSW with as little contamination of the surrounding environment as possible.
- **Leachate**- the water that leaches through the solid waste and removes various chemical compounds with which it comes into contact.
  - Leach into aquifers, rivers, streams, drinking water supplies & human habitation.
  - System of pipes is constructed below the landfill to collect leachate
  - Cover of soil & clay (cap) is installed when landfill reaches capacity.



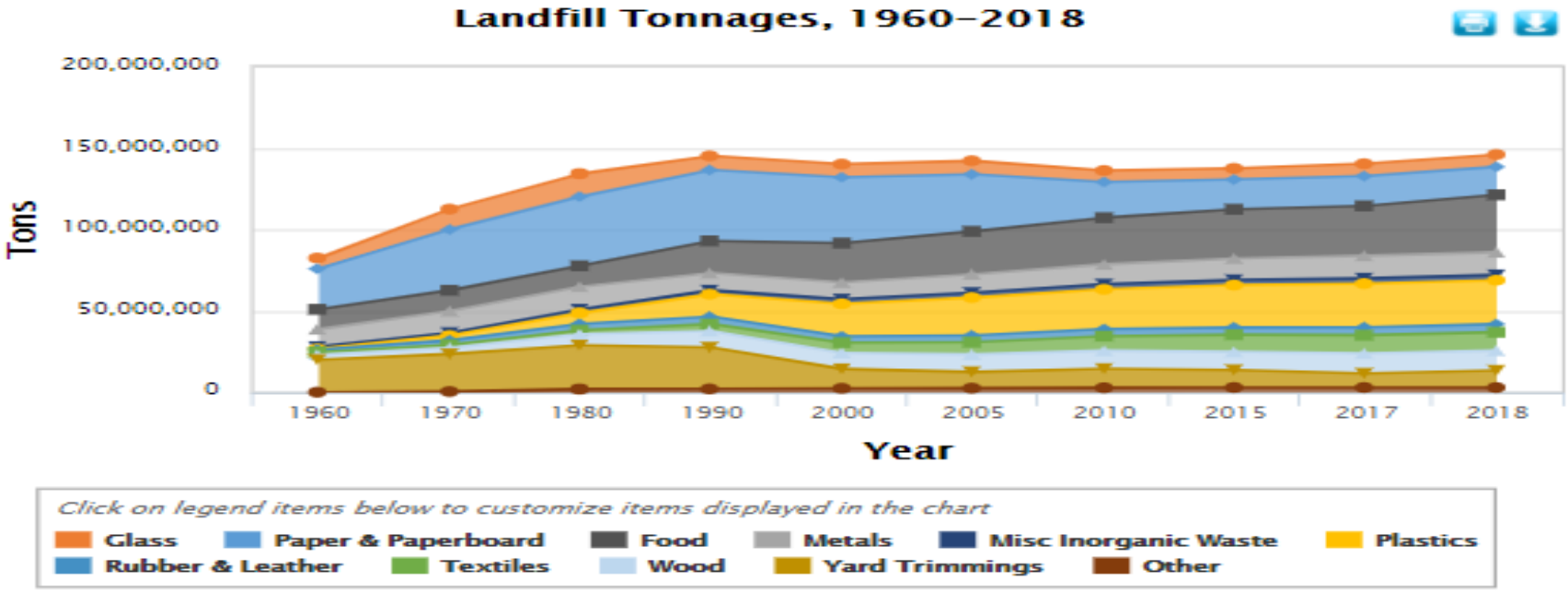
Most important component is controlling inputs…materials destined for a landfill are those with least likely to cause environmental damage through leaching.

The 2030 Food Loss & Waste reduction goal aims to reduce food waste going to landfills by 50% to 109.4 pounds per person in the U.S.

On average, it costs $30 per ton to recycle trash, $50 to send it to the landfill, and $65 to $75 to incinerate it.



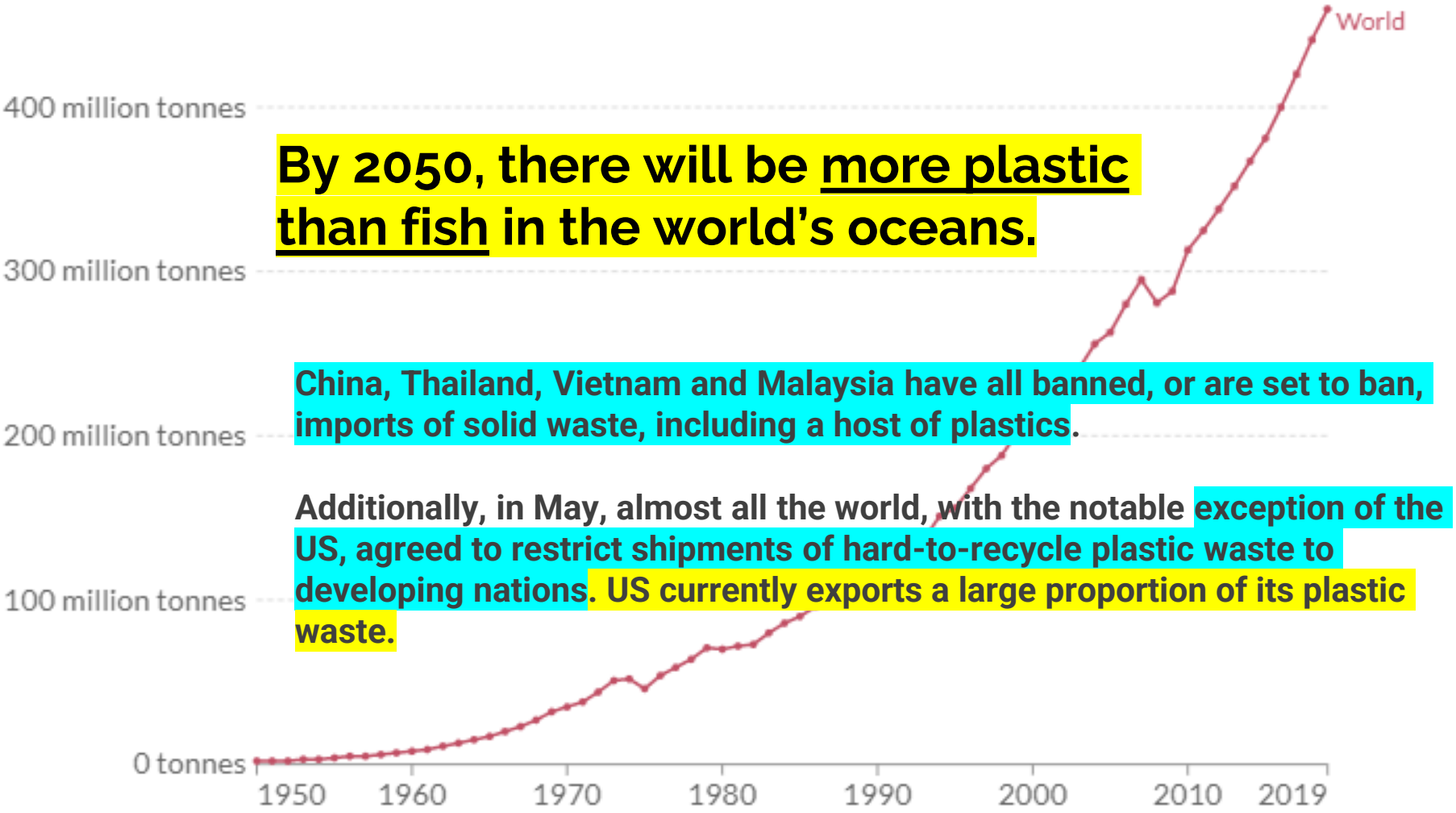
Food makes up most landfill material, followed by plastic, paper, metals, and wood.



Global plastics production

Plastic production refers to the annual production of polymer resin and fibers.

Our World in Data



By 2050, there will be more plastic than fish in the world's oceans.

China, Thailand, Vietnam and Malaysia have all banned, or are set to ban, imports of solid waste, including a host of plastics.

Additionally, in May, almost all the world, with the notable exception of the US, agreed to restrict shipments of hard-to-recycle plastic waste to developing nations. US currently exports a large proportion of its plastic waste.

Source: Our World in Data based on Geyer et al. (2017) and the OECD Global Plastics Outlook
OurWorldInData.org/plastic-pollution • CC BY

Consequences of Landfills:

- Take up space (locations – adjacent waterways) Proximity to neighborhoods (far away from population, no transporting of scavengers, pose little threat to masses)…*most ignored factor!!!!*

- Organic material is unstable – absence of oxygen, anaerobic bacteria produces *methane gas* (much more potent greenhouse gas than CO2, *can be extracted to be burned off or used as fuel*) proper ventilation piping (no trapped gases, highly explosive), not enough moisture can reduce decomposition; remains the same size after capped

- Improper lining and layering can lead into leaching...groundwater contamination *(located away from water)*

- Toxic material, such as household cleaners, oil-based paints, anything containing substantial quantities of metals (Al, Cu), automotive additives (batteries, antifreeze, motor oil…etc) should not be in landfills…leaching

Alterative from landfills are the three R's and composting…

In low-income countries, over 90% of waste is mismanaged.
This increases emissions and disaster risk,
which affects the poor disproportionately.

1/3 (extremely conservative) of solid waste is openly dumped or burned

In low-income countries, waste management costs comprise 20% of municipal budgets on average

Waste mismanaged is a global issue in terms of environmental contamination, social inclusion, and economic sustainability... *Improper disposal can lead to adverse health outcomes, for example through* ***water, soil and air contamination***

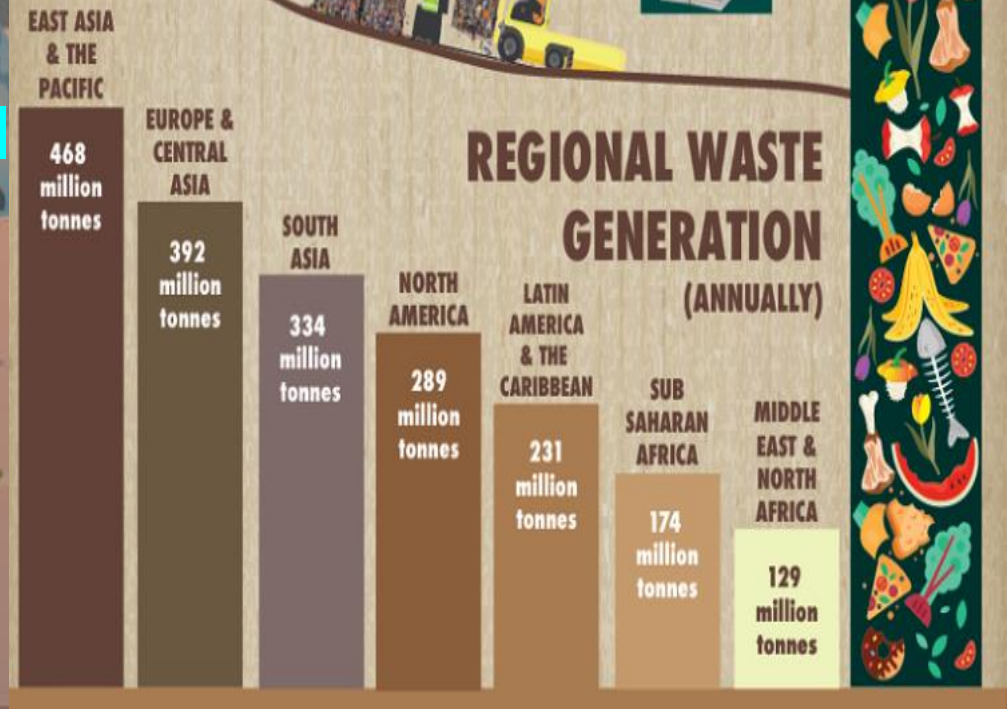
We will LITTERally be living in waste
if nothing is done.
What can we do?

The world generates **2.01 BILLION TONNES** of municipal solid waste annually.

Unless urgent action is taken, global waste will increase 70% to **3.4 BILLION TONNES** by 2050!

MAIN TYPES OF WASTE GENERATED

municipal solid waste, industrial waste, agricultural waste and hazardous waste



2. Reduce, Reuse, Recycle (3 R's)

1. **Reduce**- (most desirable); *waste minimization* or prevention
   - Input reduced=output reduced (fewer resources are being expended, source reduction provides economic benefits)
2. **Reuse**- (next desirable); *reusing* something like a disposable cup more than once.
   - allow the material to cycle w/in the system w/o additional energy or resources
3. **Recycle**- (more efficient) materials are collected and *converted into raw materials* and then used to produce new objects
   - **Greatest problem** is there is not always a market for recycled goods

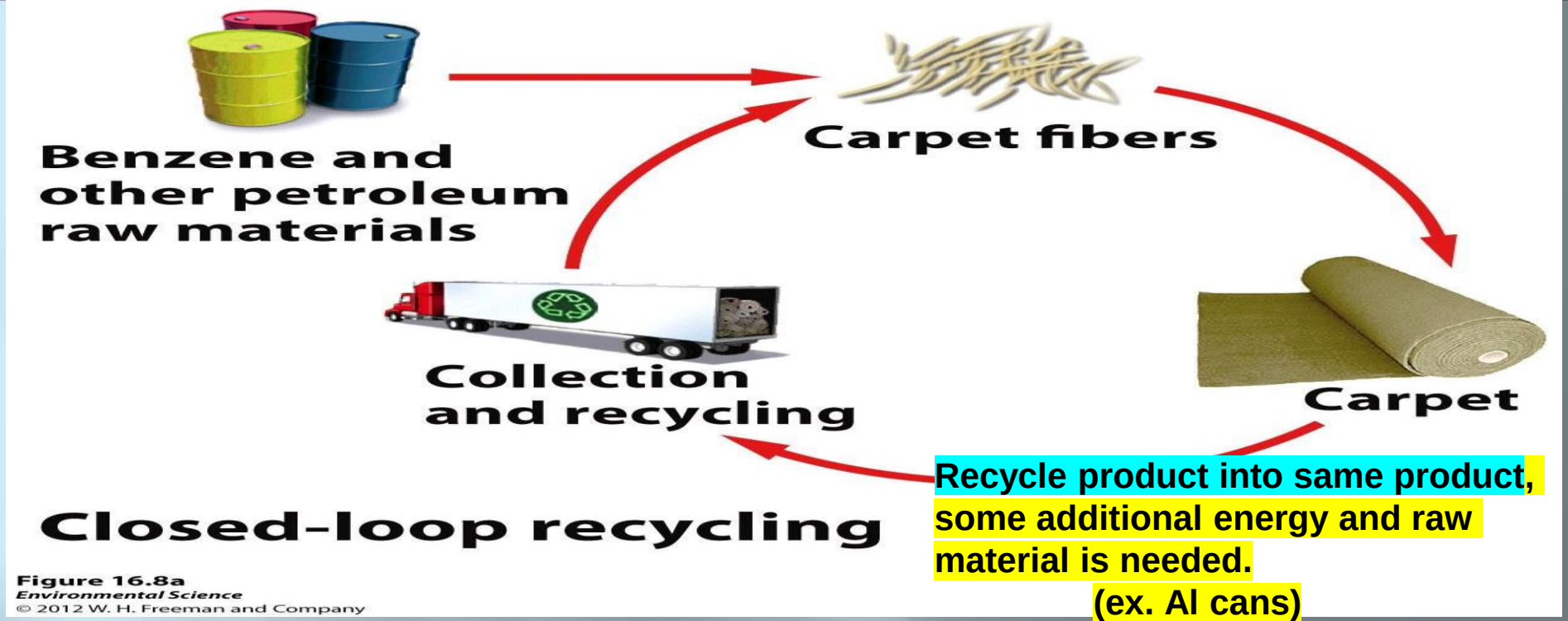


Figure 16.8a
Environmental Science

Recycle product into same product, some additional energy and raw material is needed.
(ex. Al cans)

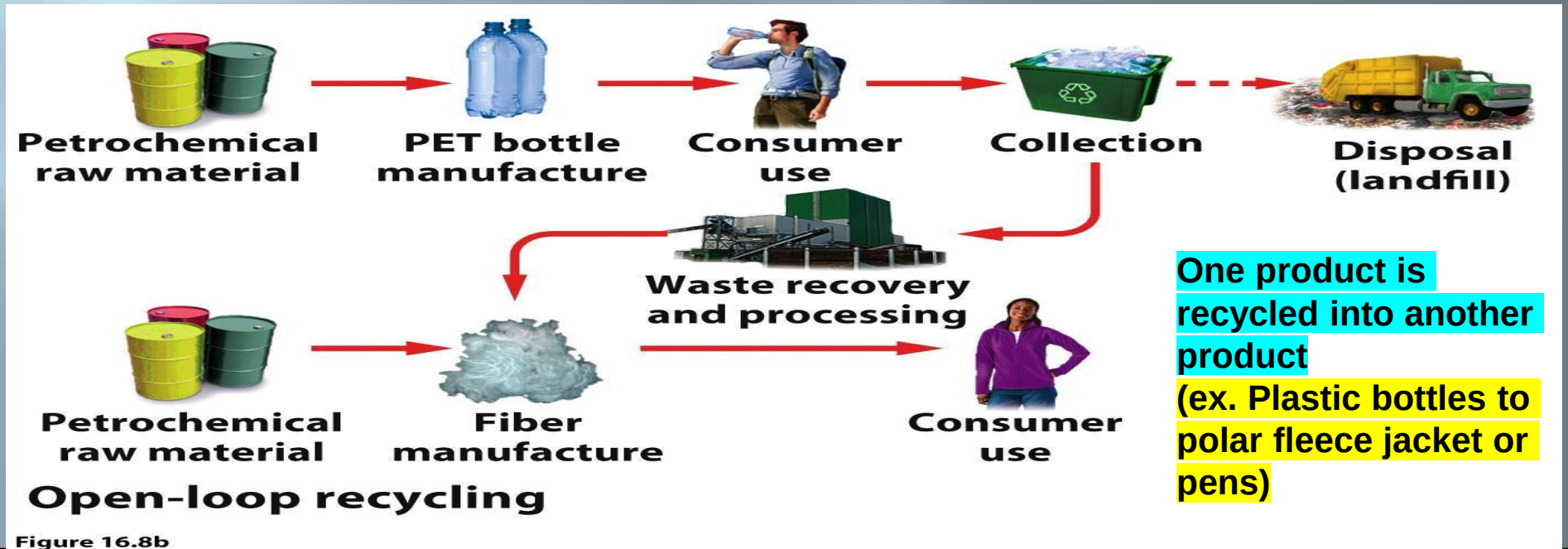
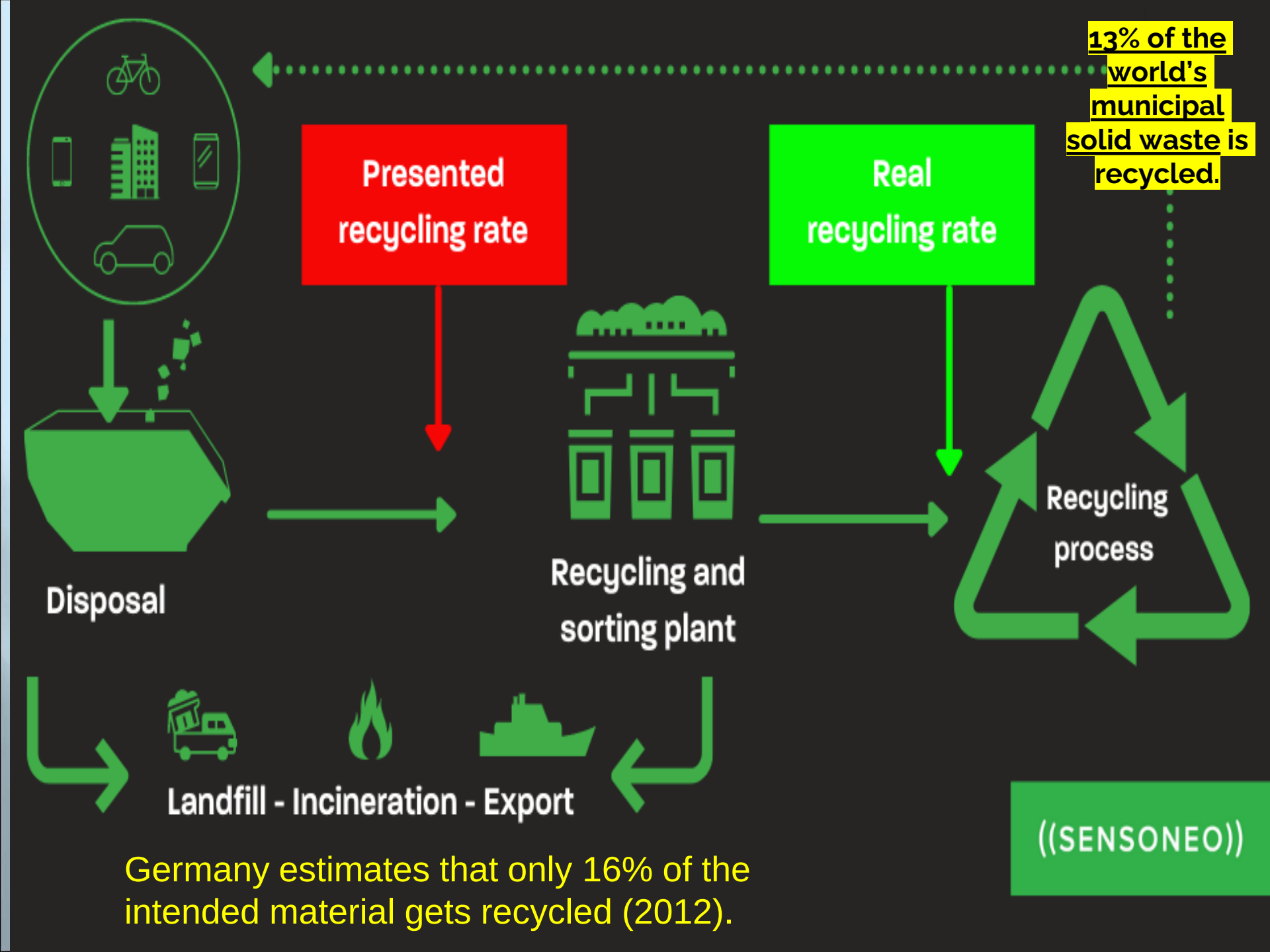


Figure 16.8b

One product is recycled into another product
(ex. Plastic bottles to polar fleece jacket or pens)



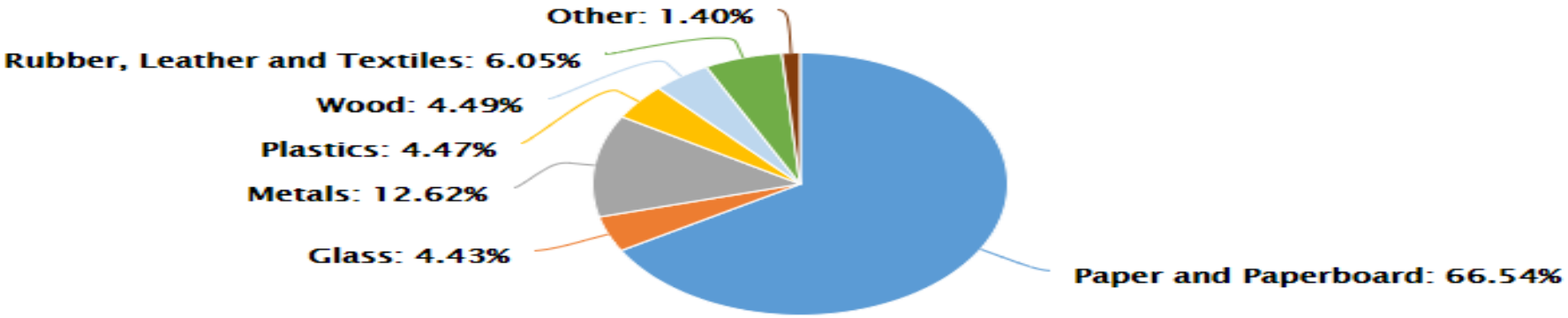
Germany estimates that only 16% of the intended material gets recycled (2012).

Most commonly used plastics

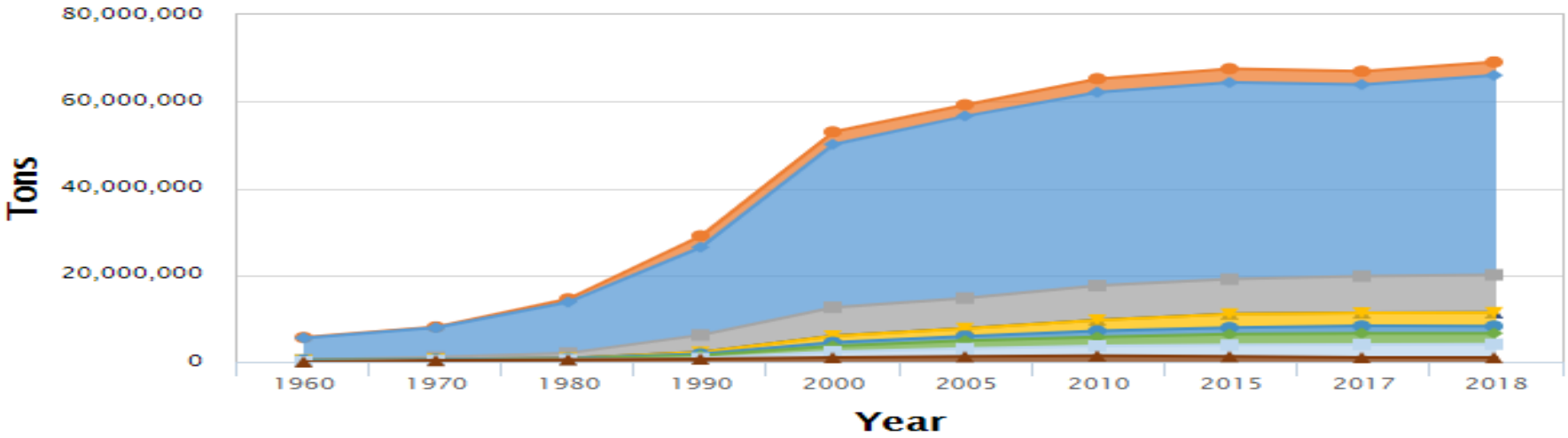
Labelling	Name	Where is it applied most often?	How long does it take to decompose (under ideal conditions)?	Recycling opportunity	Examples of use after recycling
	PET(E) - Polyethylene Terephthalate	Packaging for foods, water, soda, milk and butter; transparent shampoo bottles, disposable food containers and cups	5 -10 years	Usually recycled	Fleece clothing, pillow filler and winter clothing, furniture, ropes, garbage bags, garbage bins, car bumpers
	PEHD (HDPE) - low-pressure polyethylene (high density polyethylene)	Canisters, containers for cosmetics and household detergents, bottle caps, packets, toys	100 years	Usually recycled	Bottles and jugs, garden furniture, playground equipment, toys
	PVC - Polyvinyl Chloride	Plastic pipes, flooring, window frames, stretch ceiling, garden furniture, containers for technical liquids	Undecomposable	Sometimes recyclable	Flooring, traffic cones, payment cards, pipes
	PELD (LDPE) - low-pressure polyethylene (low density polyethylene)	Bags, film, linoleum, wire and cable cover, drinking cups	500 -1000 years	Sometimes recycled	Plastic lumber, dumpsters, compost bins, floor tiles
	PP - Polypropylene	Bottle caps, beverage straws, food containers, syringes, automobile parts	20 -30 years	Rarely recycled	Shipping skids, car battery covers, cutting boards, shovels, brooms
	PS - Polystyrene	Disposable tableware, carriers for eggs, meat, vegetables and fruit, heat insulation boards, toys	50 years	Usually recycled (but the process is complicated)	Cassette tape, mouldings, home setting items, photo frames
	O(ther)	Baby bottles, reusable water bottles, cooler bottles, children's toys, toothpaste tubes, CDs and DVDs, combo packs	Undecomposable (generally)	Hard to recycle	Combined plastic is almost never recycled

Total MSW Recycling by Material, 2018

69.1 million tons



Recycling Tonnages, 1960–2018



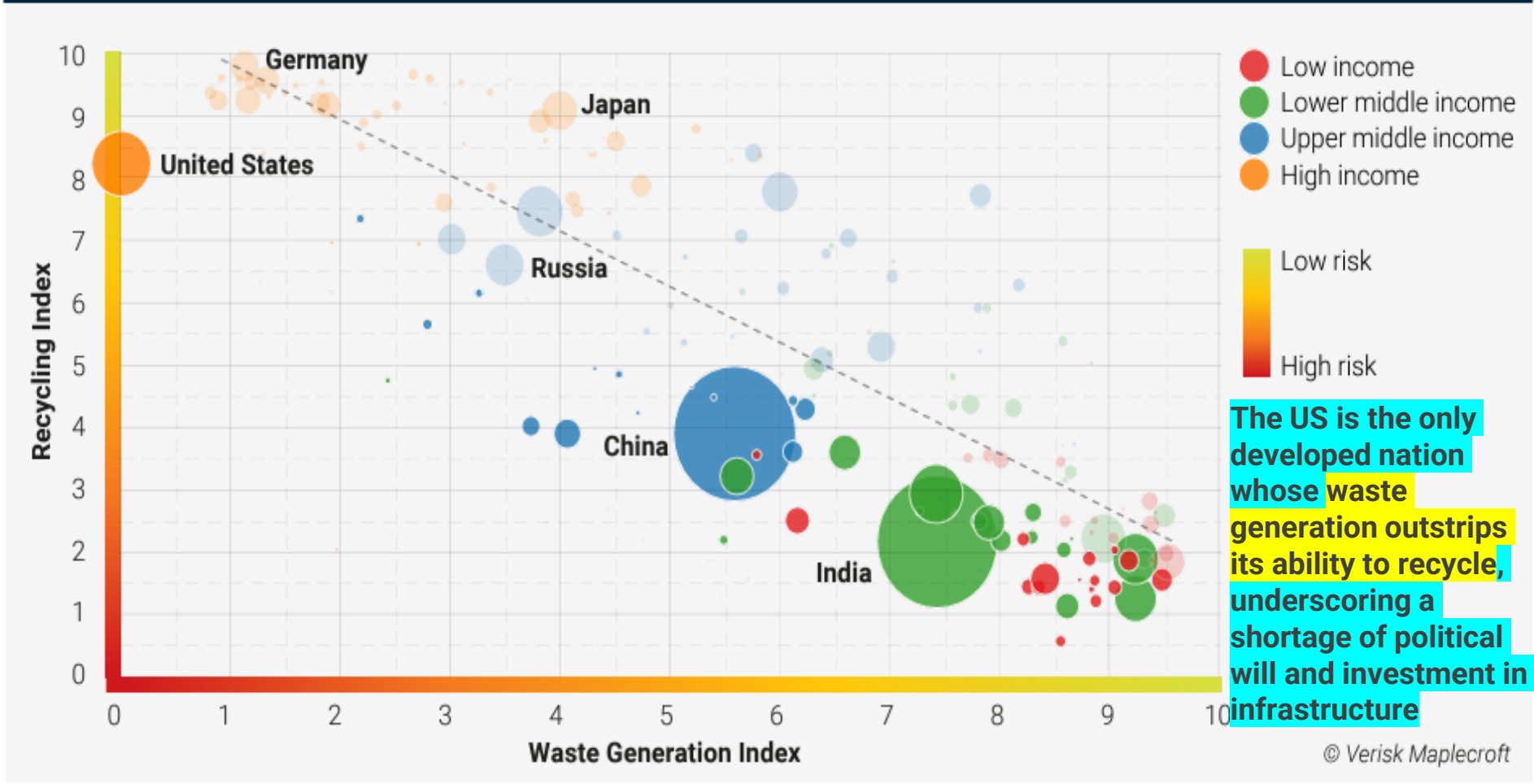
Click on legend items below to customize items displayed in the chart

Glass | Paper & Paperboard | Metals | Misc Inorganic Waste | Plastics
Rubber & Leather | Textiles | Wood | Other

Germany tops the ranking with exceptionally high levels of waste collection, recycling, compliance with international treaties and a low proportion of waste mismanaged, recycles 68% of MSW (2019)

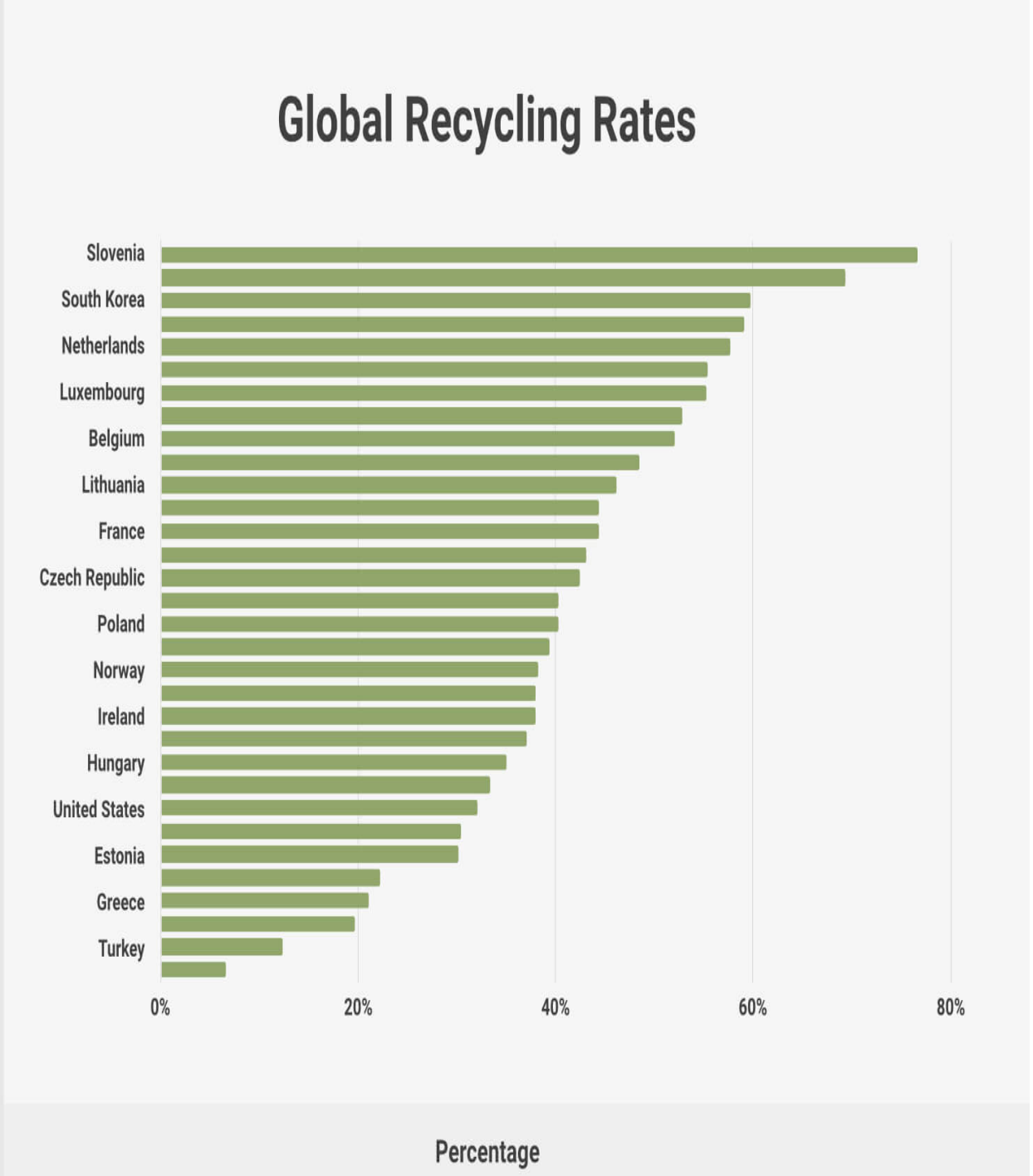
In Figure 2, it is evident that many developing economies do not have the resources to recycle efficiently, while the United States is shown as a laggard on the global stage.

Figure 2: The US lags behind other developed countries in recycling performance, despite having the highest levels of consumption globally

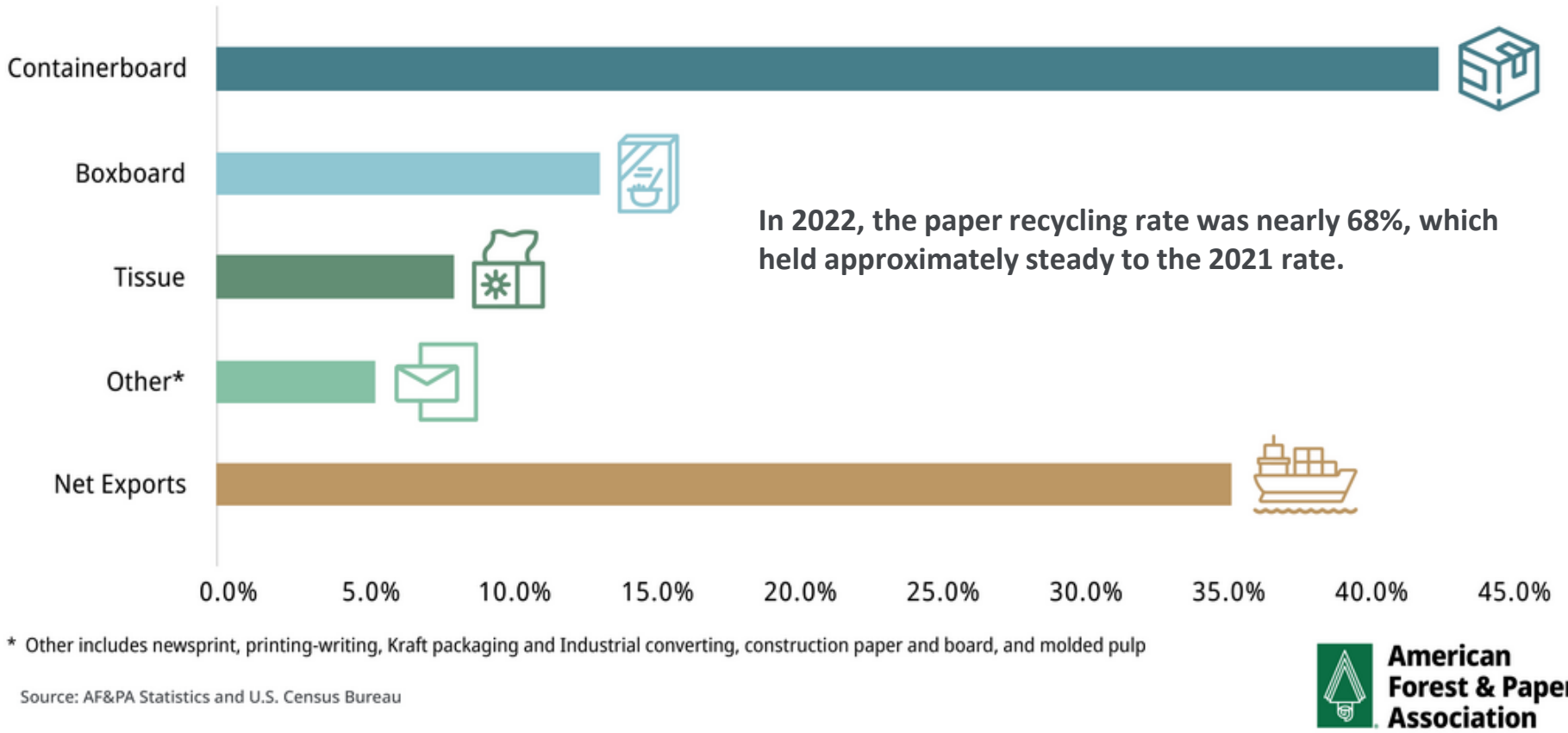


The US is the only developed nation whose waste generation outstrips its ability to recycle, underscoring a shortage of political will and investment in infrastructure

Source: Verisk Maplecroft, 2019



Country	Recycling Rates
Slovenia	76.6%
Germany	69.3%
South Korea	59.7%
Austria	59.1%
Netherlands	57.7%
Italy	55.4%
Switzerland	52.8%
Belgium	52.0%
Slovakia	48.5%
Australia	44.4%
France	44.4%
United Kingdom	43.1%
Czech Republic	42.4%
Poland	40.2%
Sweden	39.4%
Norway	38.3%
Spain	38.0%
Ireland	37.9%
Finland	37.1%
Hungary	35.0%
Denmark	33.3%
United States	32.1%
Greece	21.0%
Japan	19.6%
Turkey	12.3%



About 80% of U.S. paper mills use some recycled paper to make new and innovative products! Recycled paper is also exported. It's used in paper mills around the world to manufacture new products.

As one of the most recycled materials in the U.S., paper is a practical and sustainable choice.

3. Composting

Compost- organic material (vegetation paper fibers, feces etc) that has decomposed under controlled conditions to produce an organic-rich material that enhances soil structure, cation exchange capacity & fertility *(no meat & dairy products, do not decompose easily, smell foul).*

Figure 16.11
Environmental Science

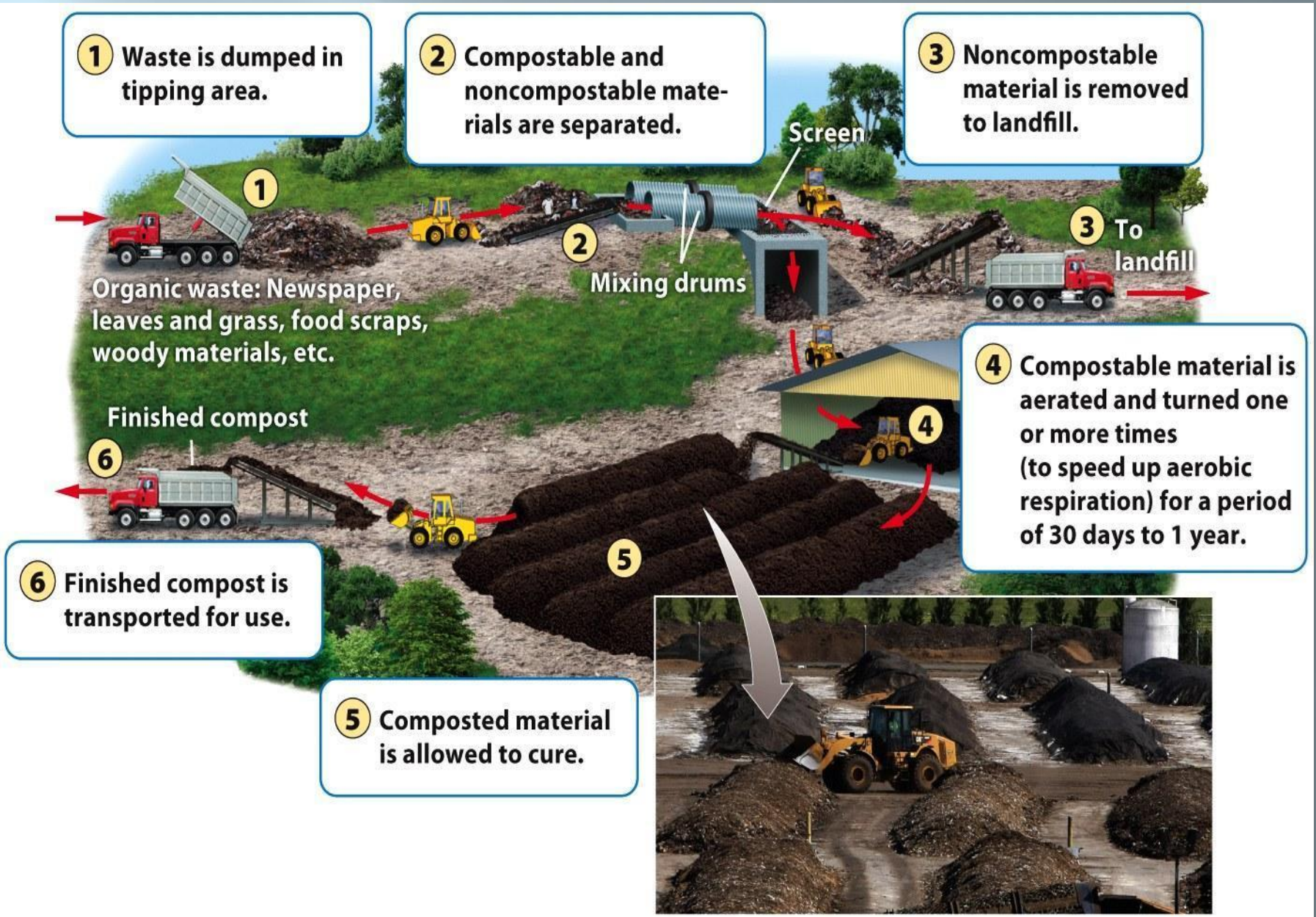
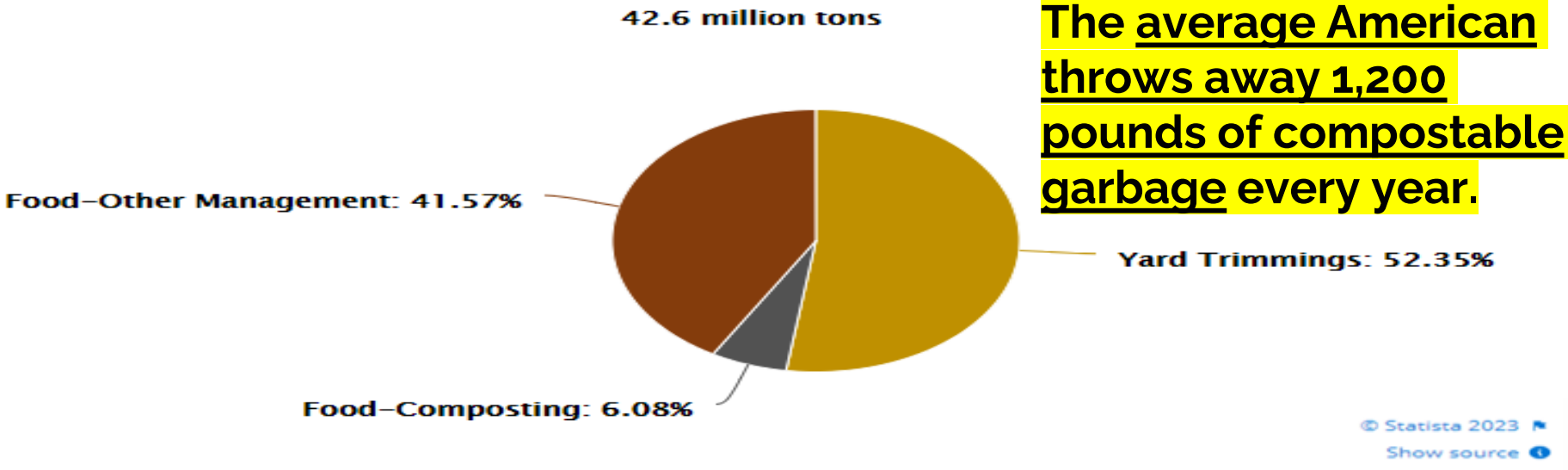


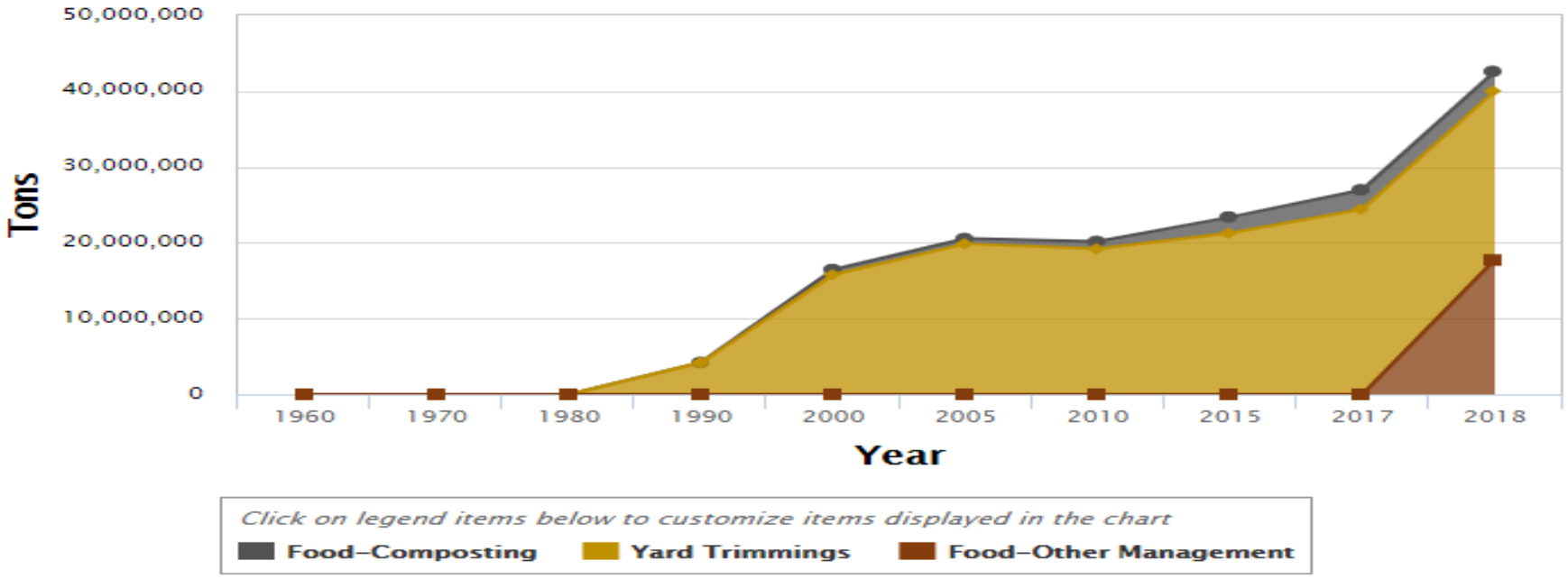
Figure 16.12
Environmental Science

Total MSW Composting and Other Food Management by Material, 2018



The average American throws away 1,200 pounds of compostable garbage every year.

Composting and Other Food Management Tonnages, 1960–2018



4. Incineration

Incineration- the process of burning waste materials to reduce its volume and mass (75%-90%) & sometimes to generate electricity and heat (byproduct ash & air pollution in the form of particular matter and gas emissions).

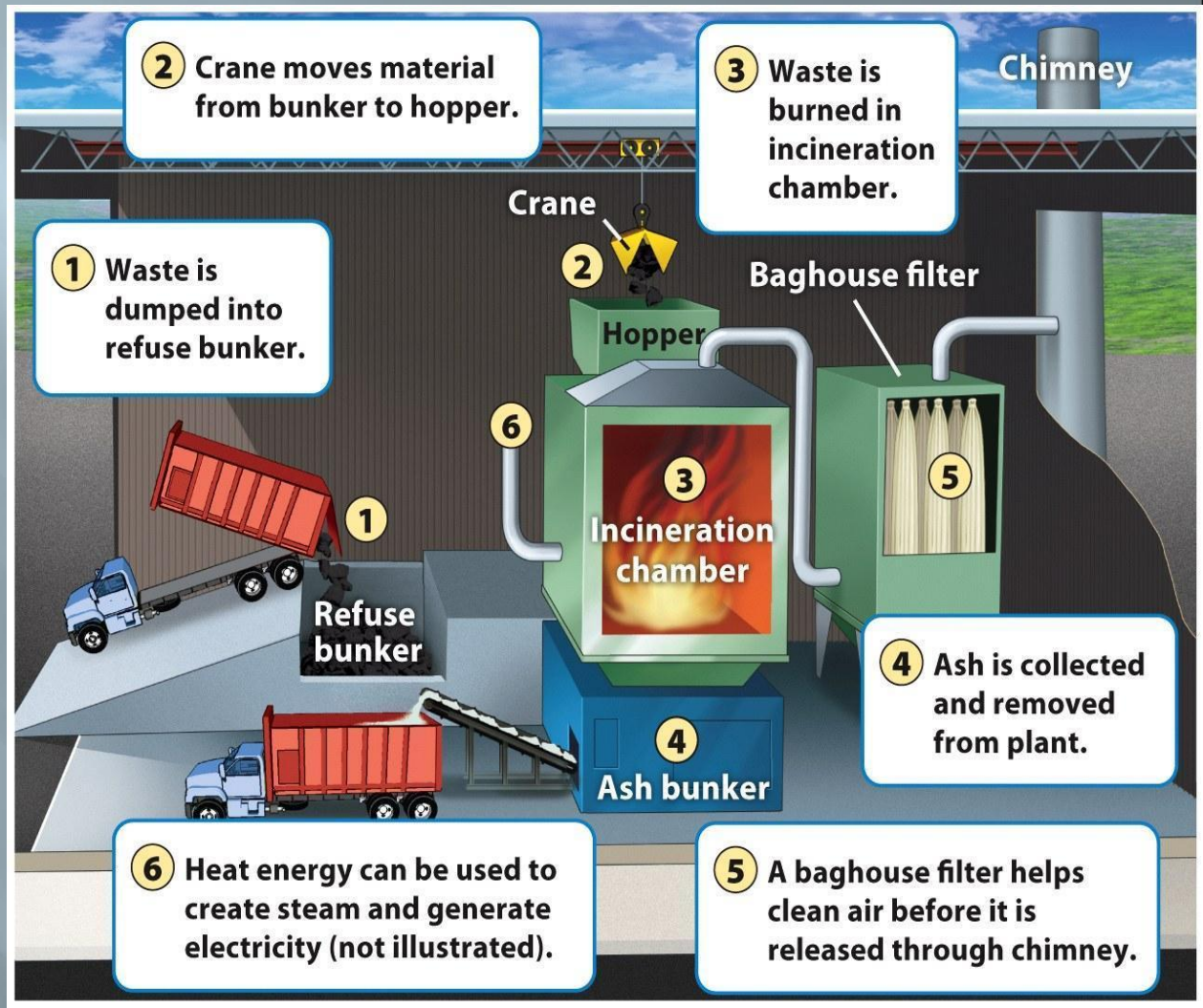


Figure 16.16
Environmental Science

Incineration Consequences

- Construction, operation, maintained costs (higher costs than landfills)
- Release air pollution & particular matter (ash – more concentrated thus more toxic, requires special landfill)
- Difficult to burn all the waste deposited…uniform burn

Best choice is the production of less material for either the landfill or the incinerator

Hazardous Waste

- **Hazardous waste**- liquid, solid, gaseous, or sludge waste material that is harmful to humans or ecosystems.
- Collection sites for hazardous waste must be staffed with specially trained personnel *(most communities do not have regular collection sites for hazardous waste, have to hold onto until periodic collections are held)*
- Hazardous waste must be treated before disposal *(making it less environmentally harmful)*
- Treatment & disposal of hazardous waste is more expensive and more difficult than ordinary MSW.

~ Waste produced by the chemical, paint, pharmaceutical, and medical industries is referred to as **hazardous waste.**

CORROSIVE
Batteries
Drain Cleaners
Oven Cleaners

TOXIC
Pesticides
Rat Poison
Pharmaceuticals
Cleaning Fluids

REACTIVE
Pool Chemicals
Ammonia
Bleach
Aerosols

FLAMMABLE
Paints, Solvents
Oils, Gasoline
BBQ Starter
Propane Cylinders

- Each year, the United States manages an estimated 35 million tons of hazardous materials. From 2001-2019, data highlights that most of the hazardous waste contains wastewater (wastes containing a large amount of water).

- As of February 2021, more than 50 million tons of hazardous waste had been thrown away globally

- The US produces an average of more than 1,700 pounds of food, plastic, and hazardous waste per person. At that rate, 5% of the world's population generates 40% of the world's waste.

- 3 billion pounds of Toxics Release Inventory (TRI) chemicals were released into the environment in 2020.

- Most of the waste created in *middle- or high-income countries* is *comprised of inorganic materials such as paper or plastic*. In contrast, developing countries are responsible for producing over half of the earth's total solid waste.

E-Waste

- **Electronic waste** (E-waste) televisions, computers, cell phones that contain toxic metals such as Hg & Cd (roughly 2% of waste stream but growing, environmental effect is greater)

Incentive to recycle these products; however, cost more to recycle than put in landfill.

Figure 16.6
Environmental Science

Laws

- ***Resource Conservation and Recovery Act (RCRA- 1976)*** – designed to protect human health & the natural environment by reducing or eliminating hazardous waste.
  - Also know as *"cradle-to-grave" tracking.*

- RCRA ensures that hazardous waste is tracked and properly disposed of.

- *In 1984,* RCRA was modified to federal ***Hazardous & Solid Waste Amendments (HSWA) – encourages*** waste minimization & phased out of the disposal of hazardous wastes on land.
  - Increased law enforcement and punish violators

Laws

- ***Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-***
  - Also know as *"Superfund Act"*.
- Puts a tax on the chemical and petroleum industries *(Superfund money).* This *revenue is used to cleanup abandoned and nonoperating hazardous waste sites* where a responsible party cannot be found (highest risk to public health).
- Requires the federal government (enforcement) to respond directly to the release of substance that may pose a threat to human health or the environment
  - EPA maintains the National Priorities list (NPL), contaminated sites (need to be rehabilitated before livable, Love Canal) that are eligible for cleanup funds

Brownfields Program

- EPA created the *Brownfields* Program to assist state and local government in cleaning up contaminated industrial & commercial land that did not achieve Superfund category.

- Contaminated industrial or commercial sites that may require environmental cleanup before they can be redeveloped or expanded.
  - Old factories, industrial areas and waterfronts, dry cleaners, gas stations, landfills, and rail yards are some examples.
- Brownfield program lacks legal liability controls to compel polluters to rehabilitate their properties (no enforcement/consequences).

Integrated Waste Management

- A method that seeks to develop as many options as possible, to reduce environmental harm and cost in a **more holistic approach**

(possibilities/solutions are endless)…

Energy From Poop??

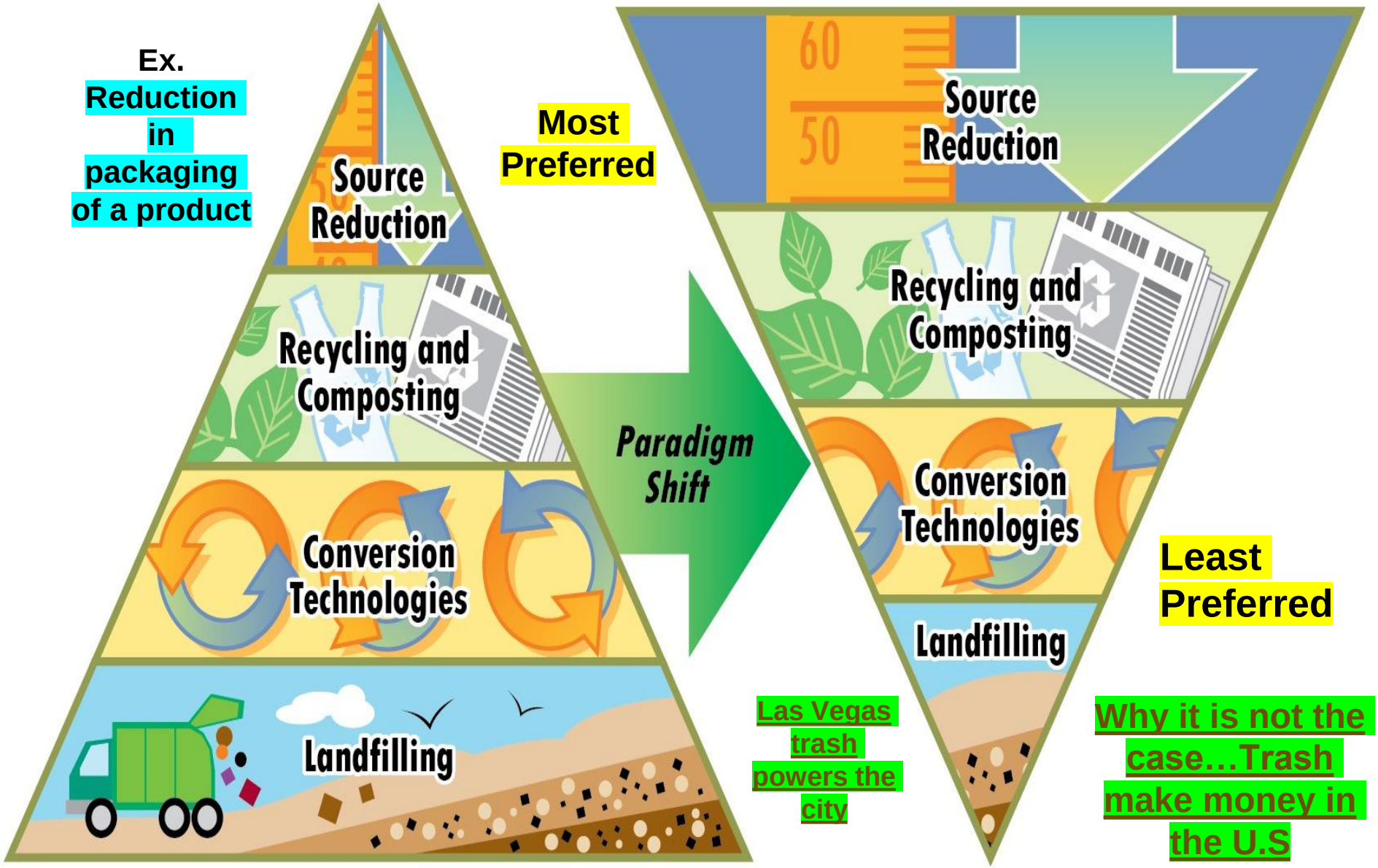
Cash from Trash…???

Cigarettes butts…

Some ways IWM is utilized:

1. Reduction
2. Composting
3. Recycling (Zero waste – San Francisco)
4. *Landfills (last resort)*
5. *Incineration (last resort)*

Ex.
Reduction in packaging of a product



Las Vegas trash powers the city

Why it is not the case…Trash make money in the U.S

Hierarchy of Preferred Solid Waste Management Strategies

Paradigm Shift for the 21st Century