Waste

Part 1:

- Relationship Between Consumption and Waste
- Definition of Waste
- Varieties of Wastes Generated
- Volumes of Waste Generated
  - US
  - Worldwide
- Projections of Waste Generation

Opening Thoughts

Perhaps most ridiculous of all is the suggestion that we 'keep' our radioactive garbage for the use of our descendants. This 'solution', I think, requires an immediate poll of the next 20,000 generations.



David R. Brower

Consumption and Waste

Role of the Consumer

"We all like to put the blame on someone else, the government, or businesses….But between 60-80 per cent of the impacts on the planet come from household consumption. If we change our consumption habits, this would have a drastic effect on our environmental footprint as well."

Source: Quote of Diana Ivanova, Norwegian Univ., in *Science Daily,* February 2016

Consumption and Waste

Waste is an extension of production/consumption and…

- Production/Consumption of goods and services is anticipated to increase at a rate faster than population growth (Ehrlich et al) and therefore waste generation is anticipated to increase at a rate faster than population growth.
- Production/Consumption (and therefore Waste) is positively linked to increases in rates of affluence (Ehrlich). As such, rises in affluence (e.g., expansion of the middle class in China) is expected to have a positive (statistically) impact on consumption and waste.*
- Waste generation levels can be influenced by Production/Consumption patterns which can be influenced by social consciousness and social pressures (i.e., by ***what*** we consume as much as by ***how much*** we consume).

* ***Boston Consulting Group (2023) estimates that the middle and upper classes in China will increase by 80 million people by 2030***

Consumption and Waste

That is to say that Consumers can affect systemic changes through:

- Changes in consumption patterns (“Just Say No”)
- Pressure on corporate policies and procedures that influence Production practices
- Becoming educated on consumption impacts
- Supporting government policies that manage consumption in a socially responsible manner (“nanny-state”?)



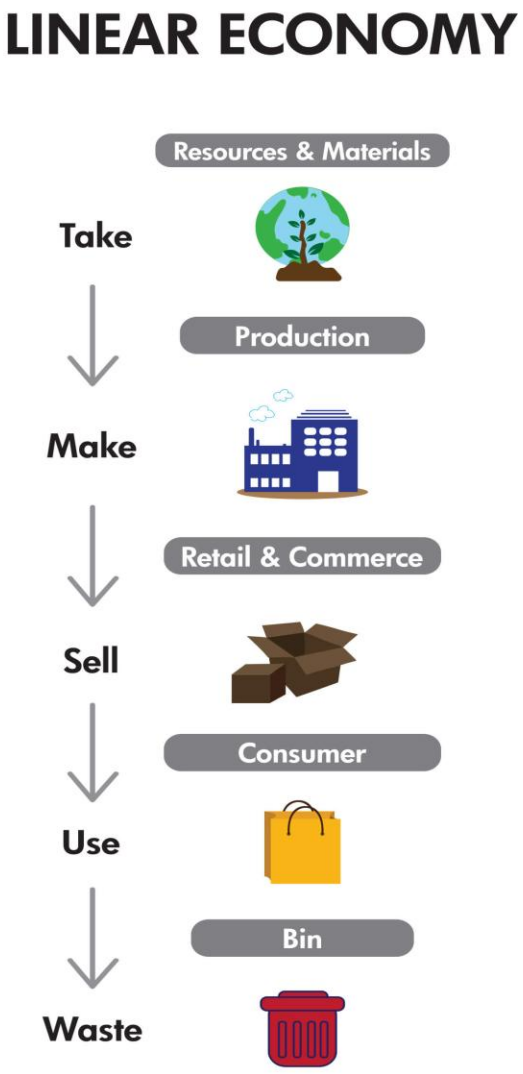
Consumption and Waste

Linear or Materials Economy

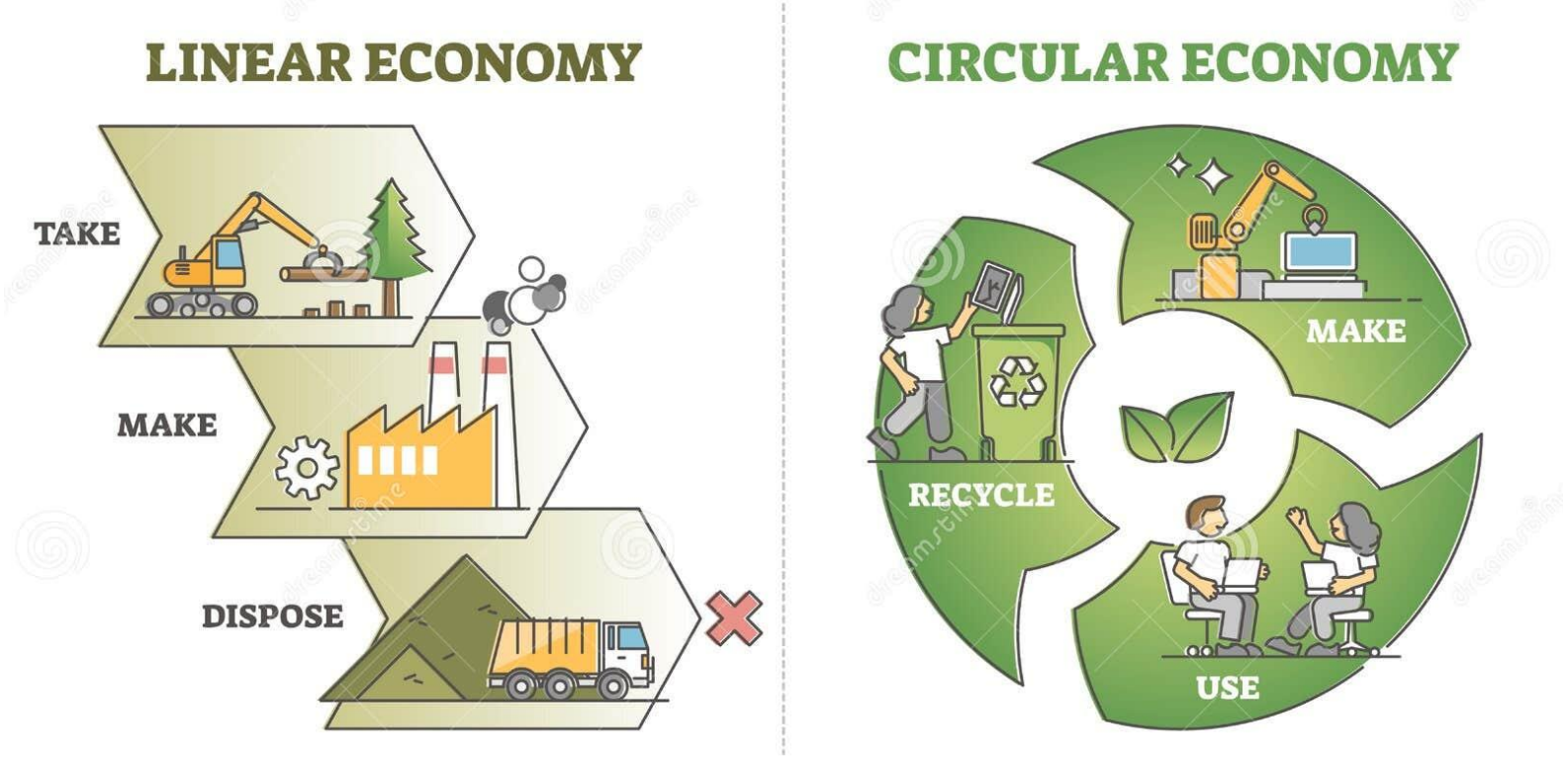
- Resource Extraction
- Production
- Transport
- Consumption

No mention of:

- Externalities
- Management of waste
- Limitations/exhaustion
- Intergenerational Obligations
- Sustainability



Linear VS Circular Economies



dreamstime.com
ID 212897645 © VectorMine

Linear VS Circular Economies

Society currently operates within the confines of the materials economy, modified by public awareness, consumer sentiment and governmental policies.

But the stress engendered by these forces is slowly shifting capitalist structures closer to the Circular Economy.

Consumption and Waste

"Built-in Obsolescence"

Designing products that wear out or become outmoded after limited use. Process intended to increase long-term consumption.

- Intentionally limited lifespans
- Consumption driven by need to replace
- Consumer becomes a "co-conspirator" to unnecessary waste generation
- Process contributes to unsustainability

Consumption and Waste

Single-use products are items designed to be discarded after a single use. As such, the product is designed largely for convenience, not durability.

In the past these consumables might be made of wood or paper, but most single use items today are made of plastic.



Consumption and Waste

While some single-use plastics may have an overt rationale for being immediately discarded (think IV tubes)*, a significant percentage of single-use items are associated with packaging.

Over 150 MMT of single-use plastic is used in packaging worldwide, with almost all of it discarded into landfills or incinerators or….



* Plastics used in medicine can, and often are, reused but must be done so in accordance with FDA regulations. Sterilization through autoclaving is possible, but expensive.

Consumption and Waste

And single use items represent the most commonly discarded item on the planet. According to the USEPA, more than 4.5 trillion cigarette butts are thrown out annually. Butts (comprised of a form of plastic) represent 38% of all items picked off beaches.

In addition, almost 400 billion plastic straws are discarded every year, many ending up in the oceans.*



* The World Economic Forum estimates that by 2050 there will be more pieces of plastic than fish in the oceans. The current estimate of plastic in the ocean is between 82 and 358 trillion pieces.

Consumption and Waste

"The one thing we reliably produce as a country — and produce more of than any other nation in the world per capita — is garbage."

From: Jake Halprin, "Big Business of Scavenging in Post-Industrial America"

But what do we mean when we use the term "garbage" or "waste"?



Defining Waste

According to Merriam-Webster, there are 165 synonyms for the word “garbage”.

Three takeaways here:

- Waste is so diverse that we need a variety of words to describe (and subdivide) the concept
- Waste has legal, social, economic, political and cultural connotations, warranting different words
- Waste is so commonplace that we often “forget” its presence.

Definition of “Waste”

What is a “waste”?

- How it is defined informs how it is quantified.
- How it is defined informs how it is managed.

The USEPA defines a waste as:

> “any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities.”

Definition of "Waste"

New York State (6NYCRR, Part 360) is slightly more verbose:

(1) *Solid waste* or *waste* means, except as described in paragraph (3) of this subdivision, discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, municipal, commercial, institutional, mining or agricultural operations or from residential activities including materials that are recycled or that may have value.

(2) A material is considered discarded if it is spent, worthless, or in excess to the generator, and is:

(i) thermally, physically, chemically or biologically processed;

(ii) disposed through discharge, deposit, injection, dumping, spilling, leaking or placement into or on any land or water so that the material or any constituent thereof may enter the environment or be emitted into the air or discharged into groundwater or surface water; or

(iii) accumulated or transferred instead of or before being processed or disposed.

(3) The following are not solid waste for the purposes of Parts 360, 361, 362, 363, 364, 365 and 366 of this Title:

(i) materials that are intended for reuse for their original function, without processing, such as materials at a garage sale, consignment shop, textile collection location or similar venue;

(ii) materials that are incorporated into food products for human consumption;

(iii) unadulterated wood generated from sources other than construction and demolition that is burned in campfires, ceremonial burns, cooking fires, wood stoves, or other similar uses;*

* ***There are nine (9) other specific exemptions to the definition of "waste".***

Definition of "Waste"

Waste: **Bi-product of social and/or industrial activities for which there is no current economic use**

Key principles in this definition:

- Waste is a result of a process (bi-product); therefore, changes to the process may result in changes to the volume and type of waste
  - This "process" is called "The Materials Economy" or "Linear Economy"
  - Valuation influences production
  - There is a difference between "waste" and "loss"
- Process "optimality" implies zero waste generation; that is, "waste" in this definition incorporates "loss" defined in food production
- Economic determination of waste may change over time; that is, what is a waste today may not be a waste tomorrow.

Definition of "Waste"

Waste: **Bi-product of social and/or industrial activities for which there is no current economic use**

Key principles in this definition (continued):

- Government can have a significant influence on waste generation. Specifically, government:
  - Has the power to classify wastes (and "declassify")
  - Can impose reasonable controls on waste management
  - Can impose fines for noncompliance
  - Can research innovative technologies
- All members of society share in the generation of wastes (directly and indirectly) and, as such, can contribute to waste management.

Waste Categories

Waste is generally categorized as:

- Non-hazardous (aka “Solid”) waste
  - Municipal Solid Waste (aka “household trash”)
  - Construction and Demolition debris
- Hazardous waste
  - Categorical and Characteristic Industrial Wastes
  - Medical waste
    - “Red bag” waste generated by medical procedures
    - Low-level radioactive waste used in hospitals
    - Pharmaceutical wastes (unused drugs and drug delivery systems)
  - Asbestos waste
  - High-level nuclear waste
- To Be Determined
  - Electronic waste (“e” waste)

Total Waste Volumes Worldwide

It is estimated that over 11 billion tonnes of waste was generated in 2022, an increase from 2021 which was an increase from 2020. This estimate includes most forms of waste:

- Solid including sewer treatment sludge,
- hazardous,
- e-waste,
- C&D (including asbestos),
- medical waste,
- Nuclear.

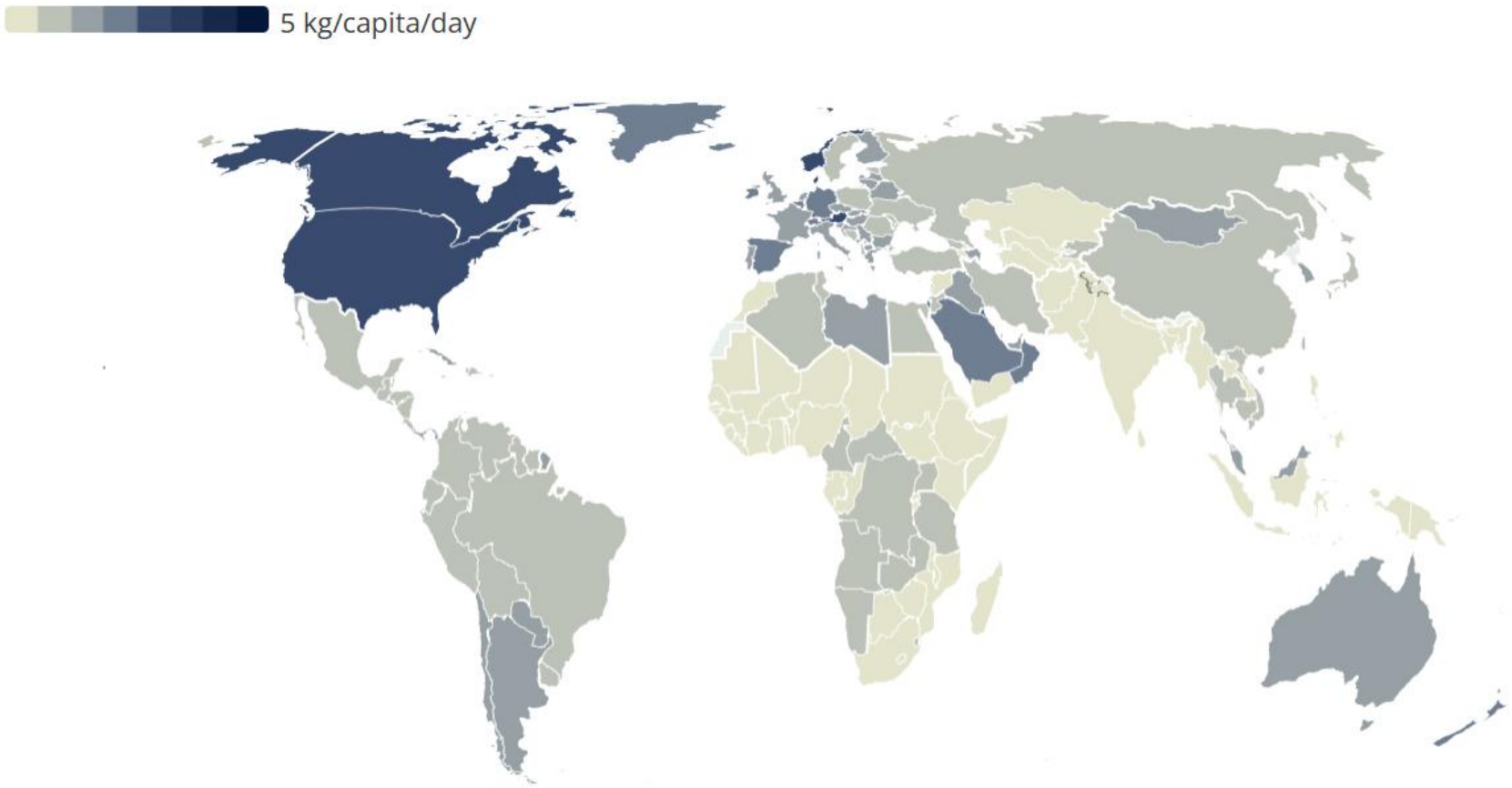
Not included in this estimate is:

- Littering
- Contaminated soil from remediation projects
- Waste left on the moon (200,000 - 500,000 lbs. and rising)

Total Waste Volumes Worldwide

11 billion tonnes of waste is the equivalent of **8.4 lbs./person/day.**

But each person does not generate the same amount of waste. Wealthy nations generate **almost 20 times** the waste generated by poorer nations. The average US citizen contributes 4.9 pounds per day; a citizen of contributes 0.4 pounds.

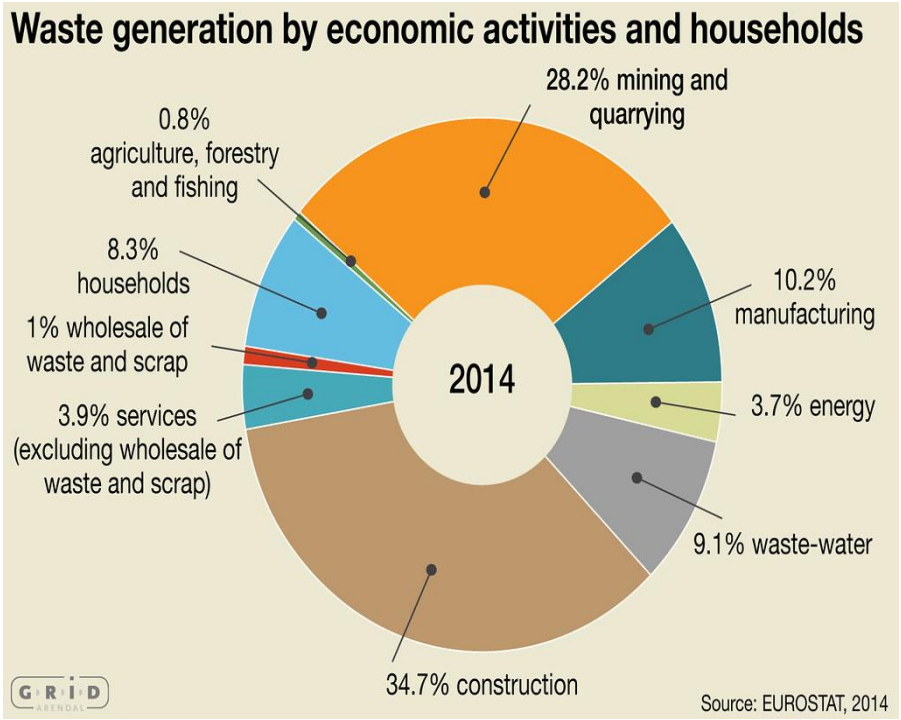


Waste by Category

The solid waste comes from different sources but most waste is generated ***on behalf*** of the individual, not by the individual.

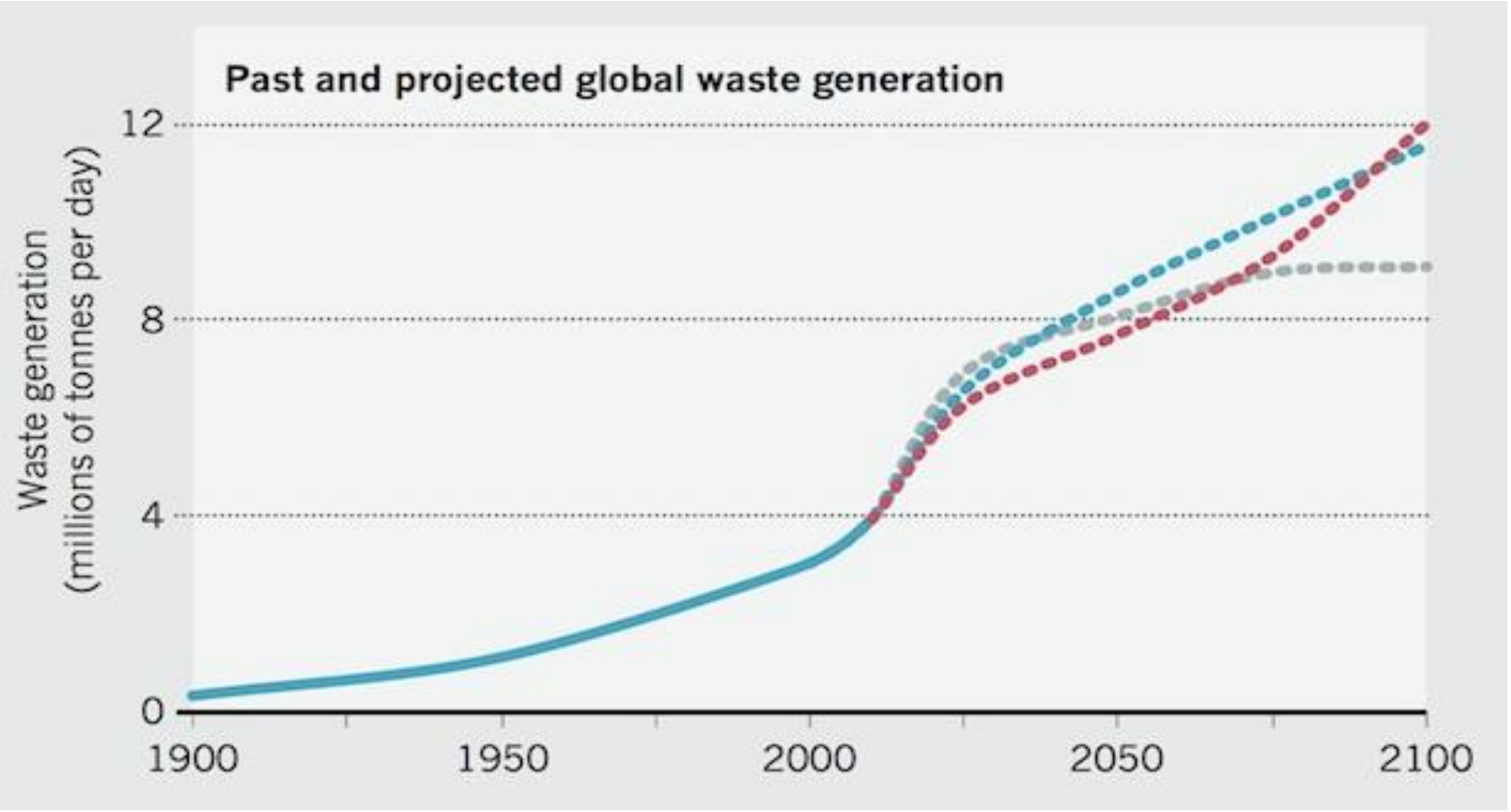
Less than 10% of all waste originates from a residential household*.

Source: European data (Eurostat), 2016.

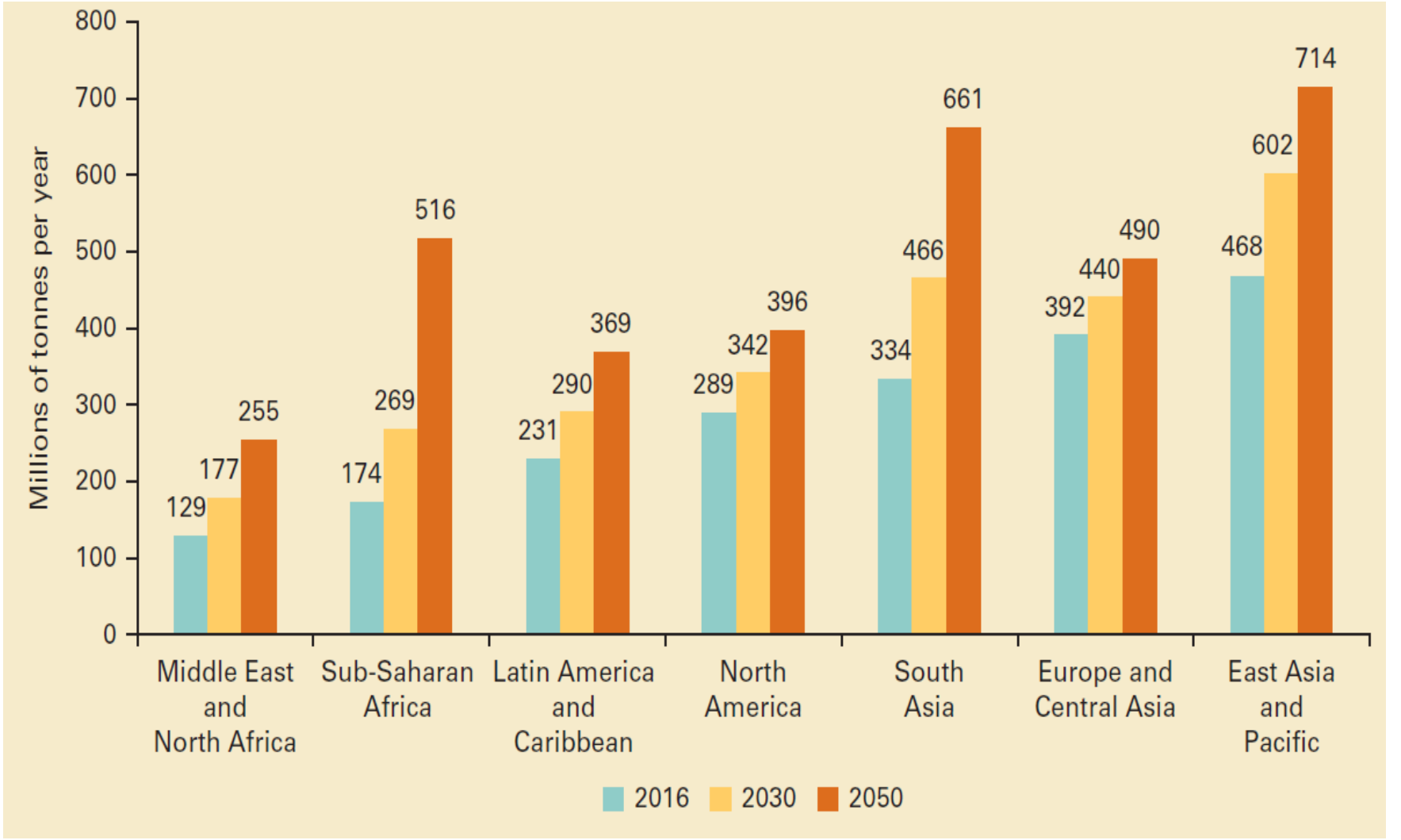


Total Waste Volumes Worldwide

And the volumes of waste will increase in the future. The World Bank is projecting that solid waste volumes could triple by 2100 while population is expected to increase by only 80%.

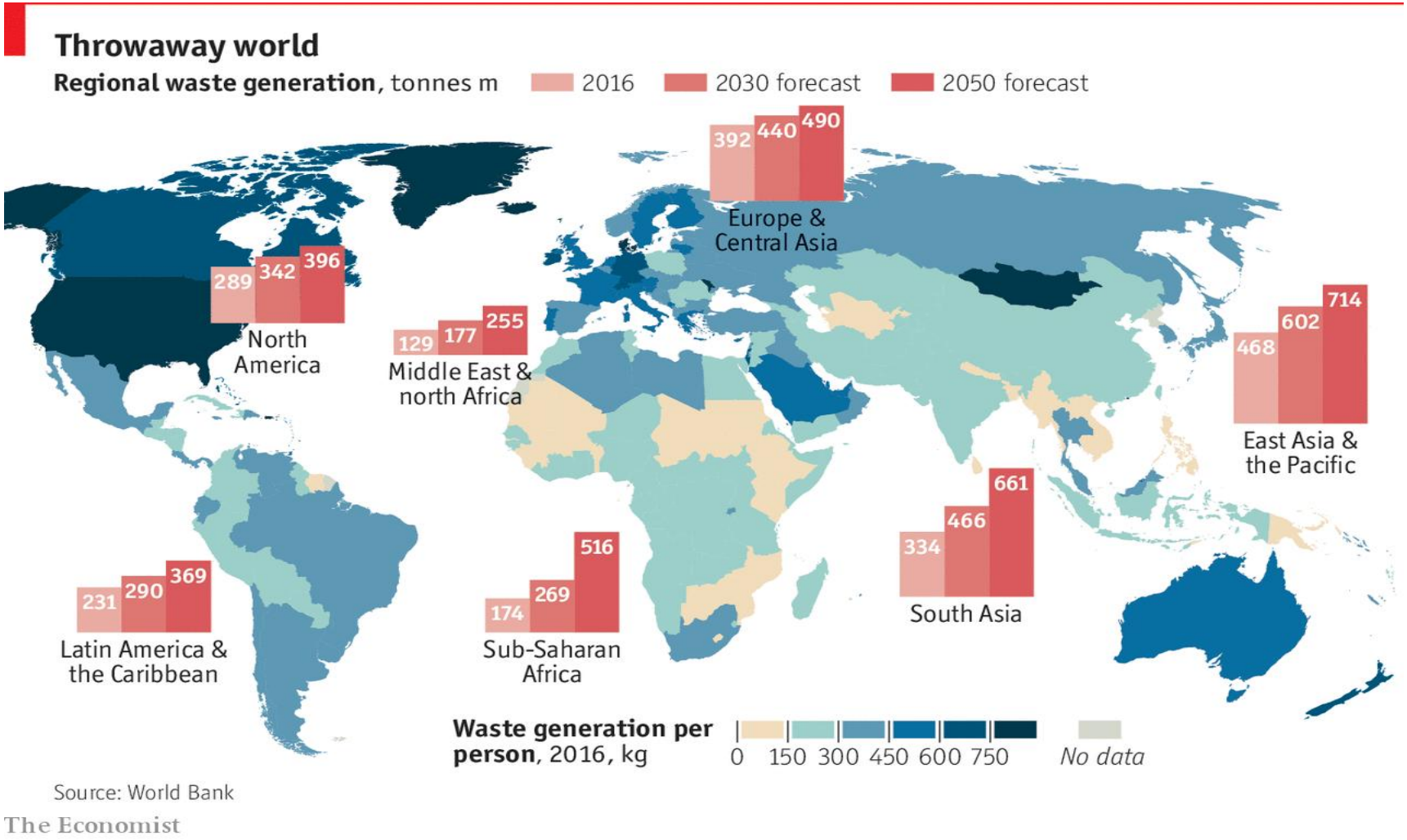


Waste generation is anticipated to grow in all regions of the world, according to the World Bank (2026). The rate of growth will vary; in the US waste volumes are anticipated to increase 15% from 2030 to 2050 while waste generation is anticipated to grow over 40% in Southeast Asian nations.



Waste volumes/masses are increasing every year as:

- Population increases
- Affluence expands (Paul Ehrlich)



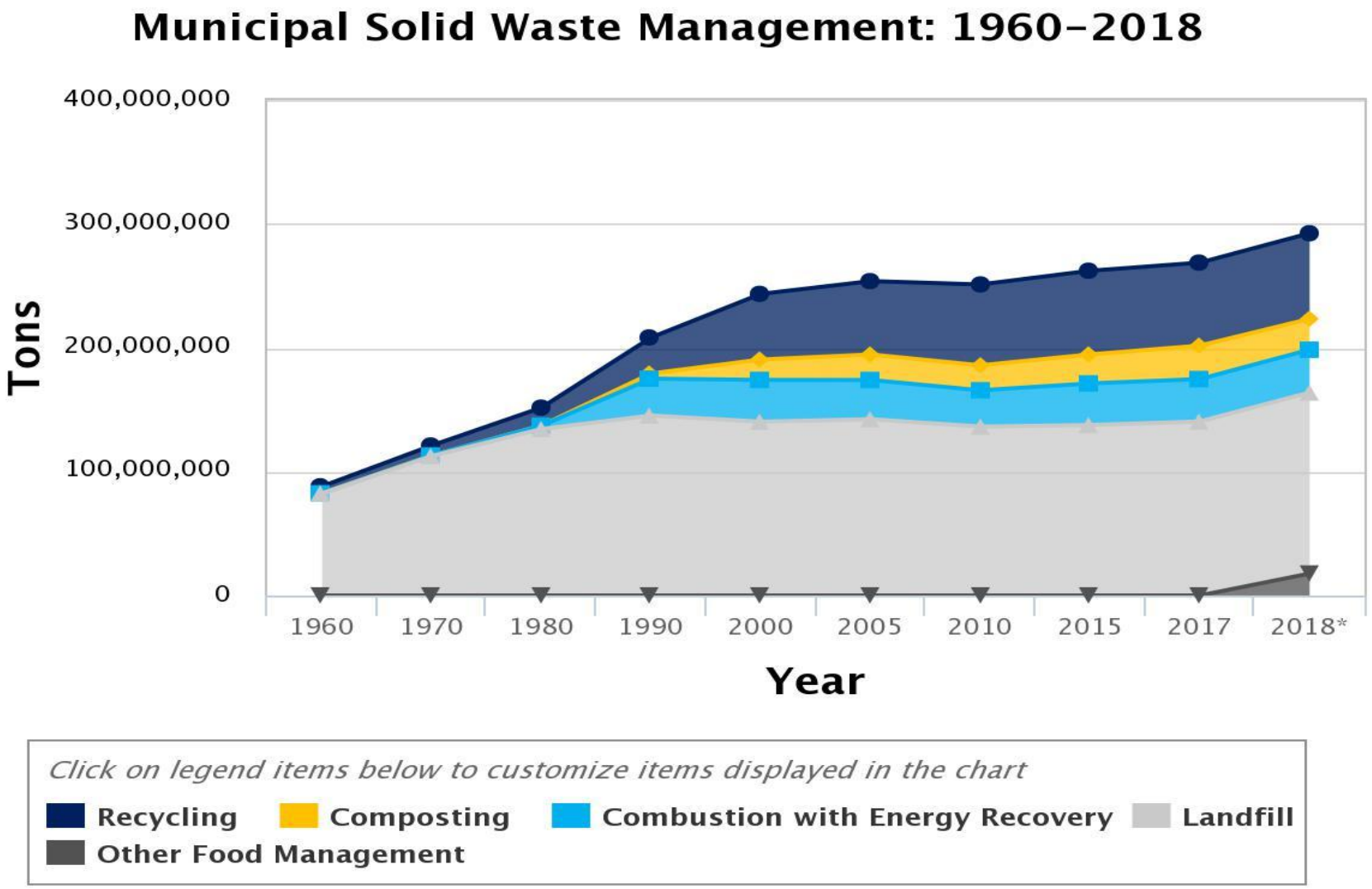


Solid Waste

- **Non-hazardous (aka "Solid") waste**
  - **Municipal Solid Waste (aka "household trash")**
  - **Construction and Demolition debris**
  - **Industrial waste**
  - **Electronic waste ("e" waste)**

Solid Waste Profile: US

Per Capita MSW Generation

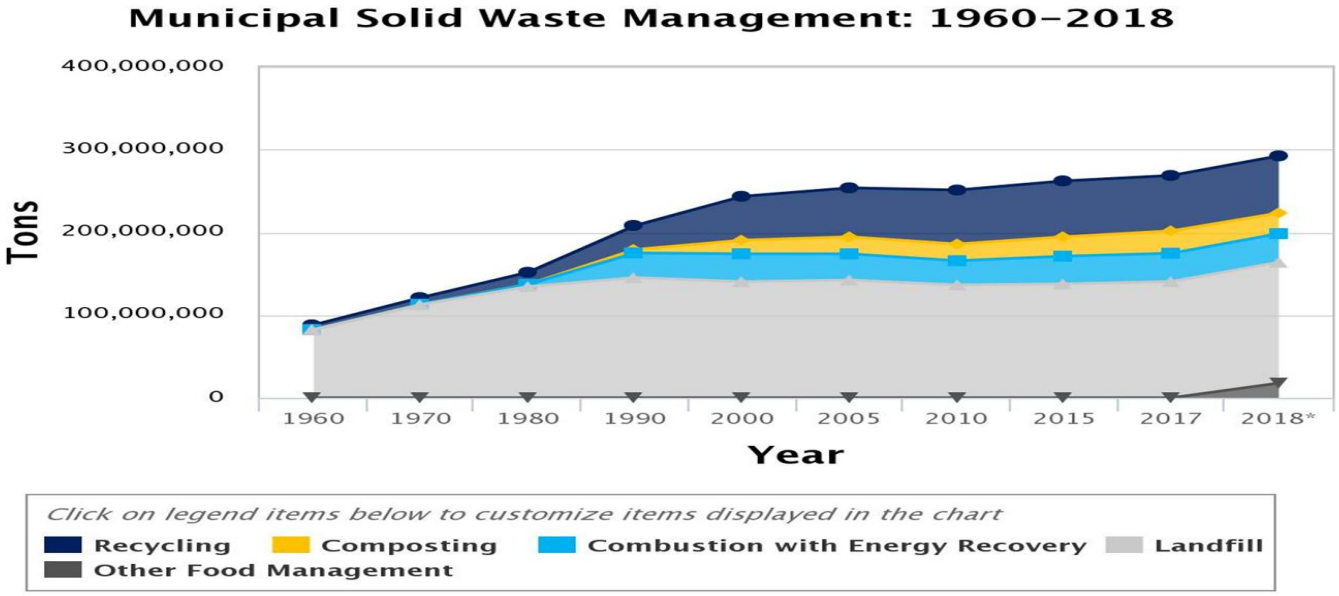


Solid Waste Profile: US

Per Capita MSW Generation

MSW includes all wastes collected and processed at regulated solid waste facilities. MSW does **NOT** include:

- Litter and Illegal waste
- E-waste
- C&D
- Contaminated soil from remediation projects
- Hazardous wastes and Medical Waste

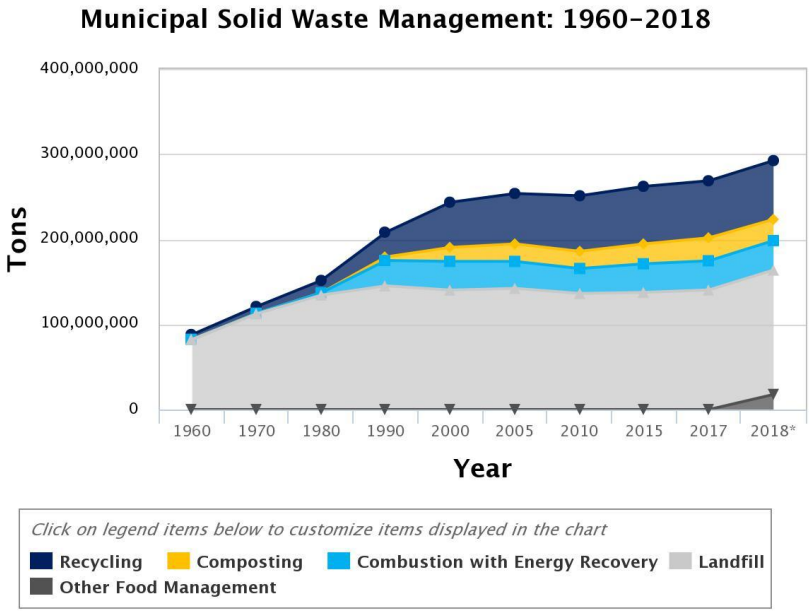


Solid Waste Profile: US

Total and Per Capita MSW Generation

Comments on Graph:

- Total MSW generation was 292.4 million tons, an increase of 23.7 million tons over 2017. This 8% increase reflects a change in EPA data collection rather than a change in waste generation.
- MSW generation on a per capita basis has increased from 2.68 lbs. (1960) to 4.9 lbs. per day (2018). Each person in this country is responsible for almost 1,800 pounds per year of MSW (this value does not include other forms of waste, including hazardous waste).
- Irrespective of the comment above, MSW generation (total and per capita) has remained relatively constant over the past 15-20 years.



Solid Waste Profile: US

Recycling

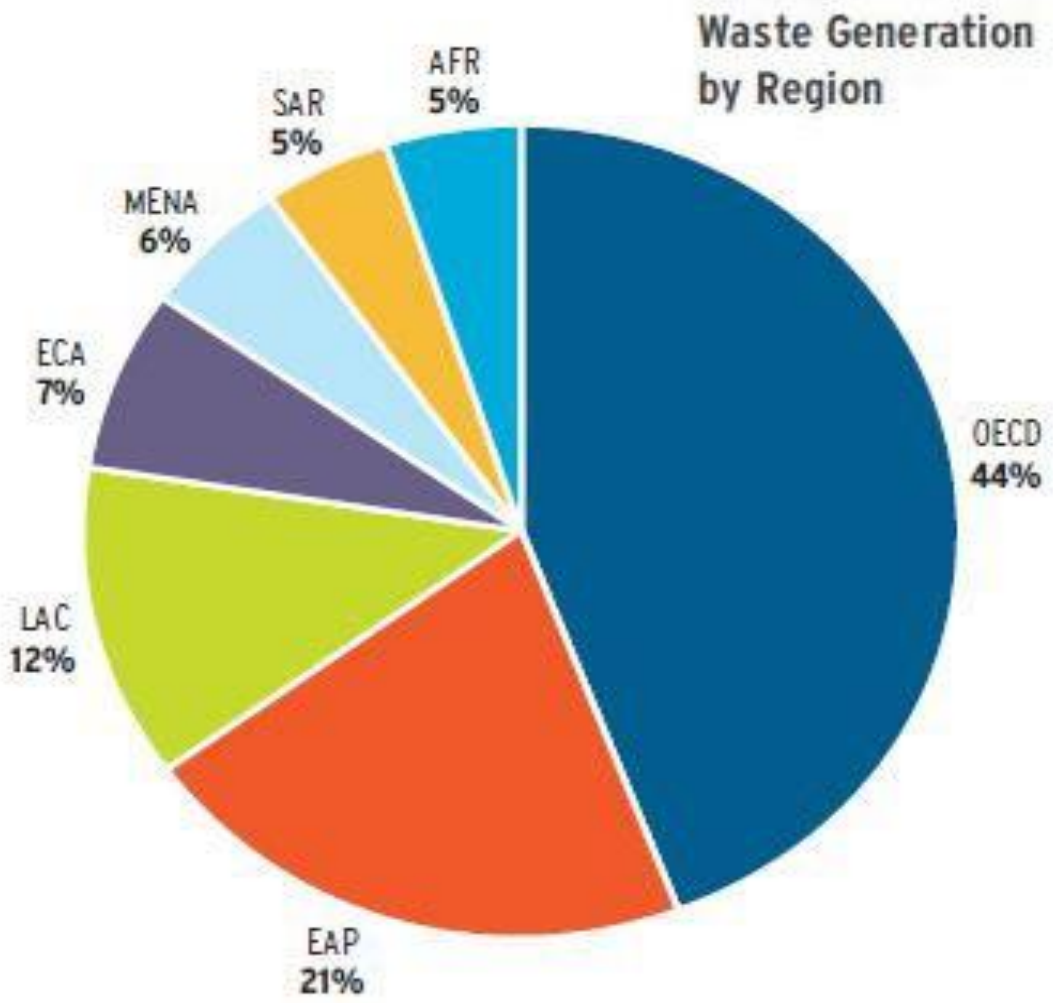
Comments on Previous Graphs:

- Most components of MSW can be recycled, but only one-third of everything thrown away is, in fact, recycled.
- Percentage of total MSW recycled has remained relatively constant over the past 15 years (since 2005). Recycling rates were 6% in 1960, rising to a peak level of 35% in 2017 before decreasing slightly to 32% in 2018.
- Percentages only refer to MSW (see slide above) so actual recycled rates are much lower than shown.

Solid Waste Profile: World



Solid Waste Profile: World



Solid Waste Profile: World

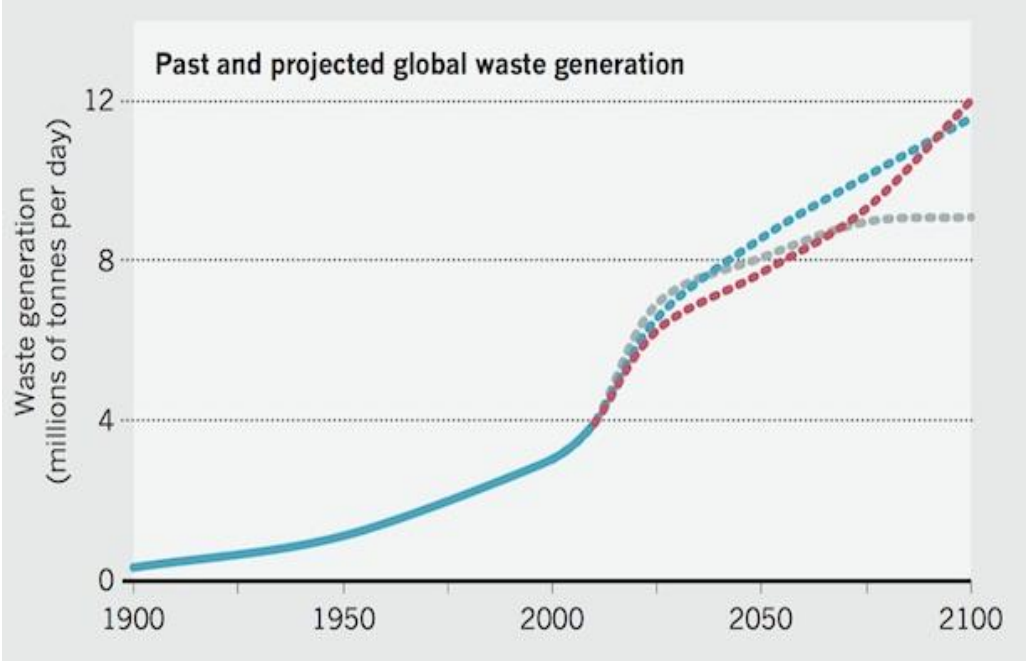
Comments:

- The majority of the waste generated in the world is by residents of the developed world (add OECD to EAP).
- Much of the developed world (excepting Denmark) generates less waste per capita than the US
- The majority of future wastes will be generated by the developing world and most of that waste today is poorly managed.

Solid Waste Profile: World

Around the world, waste generation rates are rising. In 2016, the worlds' cities generated 2.01 billion tons of solid waste, amounting to a footprint of 0.74 kilograms per person per day. With rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tons in 2050.

Source: World Bank (2022)



Solid Waste Profile: World

Without urgent action, global waste will increase by 70 percent on current levels by 2050, according to the World Bank's new (2026) ***What a Waste 3.0: A Global Snapshot of Solid Waste Management to 2050*** report.

Driven by rapid urbanization and growing populations, global annual waste generation is expected to jump to 3.9 billion tonnes over the next 30 years, up from 2.6 billion tonnes in 2022, the report finds.

Although they only account for 16 percent of the world's population, high-income countries combined are generating more than one-third (34 percent) of the world's waste. The East Asia and Pacific region is responsible for generating close to a quarter (23 percent) of all waste. And by 2050, waste generation in Sub-Saharan Africa is expected to more than triple from current levels, while South Asia will more than double its waste stream.

Source: World Bank Press Release (9/20/2018)



Hazardous Waste

Hazardous waste is a waste that warrants special handling, including:

- Toxic waste
- Medical waste (including low-level radioactive waste)
- Asbestos waste
- High-level nuclear waste (discussed previously)
- Household hazardous waste (e.g., batteries)
- E-waste (if tested)

Hazardous Waste

"Hazardous" wastes are a special category of wastes requiring special handling and management

Definition of Hazardous Waste as provided in USEPA RCRA (1976) and the 1989 Basel Convention:

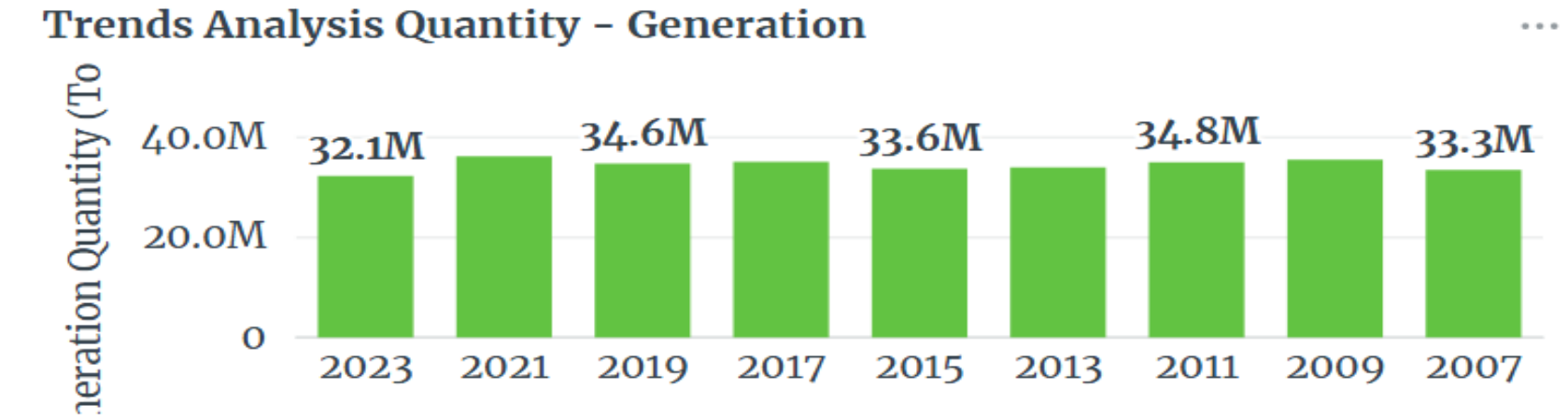
- Categorical waste (waste generated by a particular process involving hazardous constituents
- Characteristic wastes (toxic, reactive, corrosive, or flammable)

Hazardous Waste

Worldwide, **between 350 and 430 million tons** of hazardous waste is produced each year - almost 13 tons a second. Roughly 100-115 pounds of hazardous waste are generated annually for every single person in the world. Worldwide Hazardous Waste volumes are increasing.



Hazardous Waste



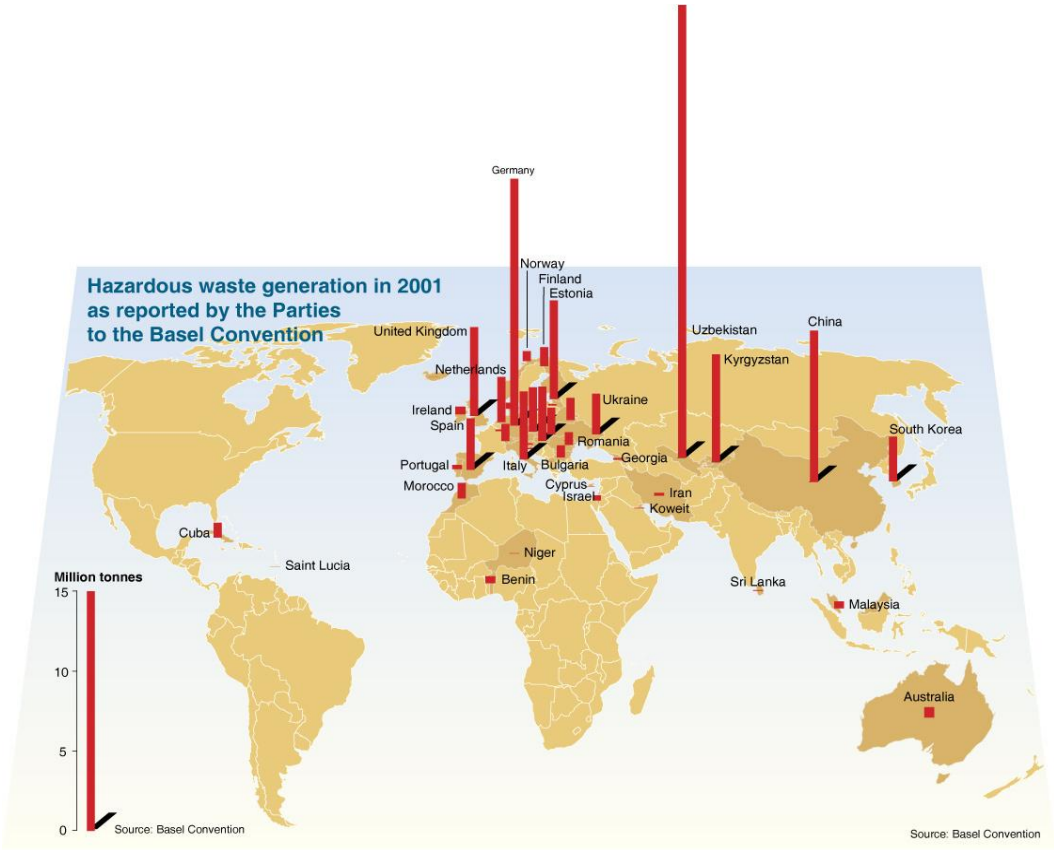
In the US, around 33 million tons of hazardous waste was reported by large quantity generators* in the United States, annually for the past 20 years (USEPA). Since 2001, the quantity of managed hazardous waste has decreased by approximately 5.6 million tons.

* Small quantity generators contract with regulated waste haulers who qualify as Large quantity generators. In this way, all hazardous waste (including household wastes collected at repositories, is considered included within this volume.

Hazardous Waste

Since 2001, the volume of non-US hazardous waste has increased an estimated 4000%. Reasons for this increase:

- Industrial expansion in non-developed nations
- Revisions to regulations redefining wastes.



Hazardous Waste

What are the previous slides telling us?

- Hazardous waste is a significantly smaller volume (roughly one-tenth) of solid waste.
- Hazardous waste volumes are increasing worldwide while decreasing in the US. The implication is that the US is "exporting" its waste.
- The US is 4% of the world's population but generates 10% of the world's hazardous waste. This is consistent with solid waste data (US generates almost 15% of worldwide solid waste).
- Hazardous waste generation is connected to economic growth; as economic activity increases, hazardous waste increases.

Hazardous Waste

What are the previous slides NOT telling us?

- Hazardous waste is poorly tracked outside of the developed world. Much of the waste (one estimate puts this at 40%) in the developing world is disposed of illegally.
- Even in areas of proper management (e.g., US) hazardous waste represents a threat to ecosystems. In the US, 40% of all groundwater resources are contaminated from hazardous substances (USEPA).
- Hazardous waste generated overseas is often connected to US Corporations (Dupont).

Nuclear Waste

"Nuclear waste" is a subset of the larger category of Radioactive Waste (any waste that contains measurable concentrations of radioactive elements). Radioactive waste is generated from medical facilities, research laboratories, defense contractors, and commercial power plants.

Discussed herein is the last category: nuclear waste from power plants. This waste accounts for only 5% of all radioactive waste.*

* Source: IAEA "Global Overview of Radioactive Waste and Spent Fuel Management" (1/21/2021)

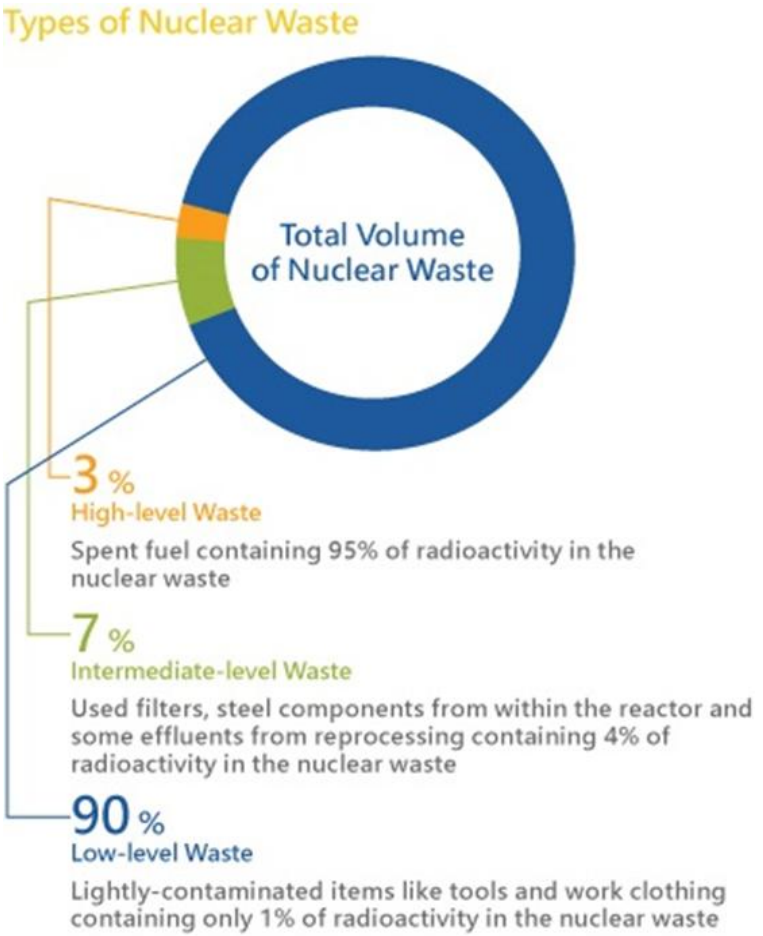


Nuclear Waste

Nuclear waste is further divided into Low-level waste (LLW) and High-level waste (HLW). The distinction is based on levels of residual radioactivity.

LLW consists of clothing, paper, tools and other items that are discarded at power plants and which have absorbed radioactive elements.

HLW is almost exclusively spent nuclear fuel and the metal rods containing that fuel.

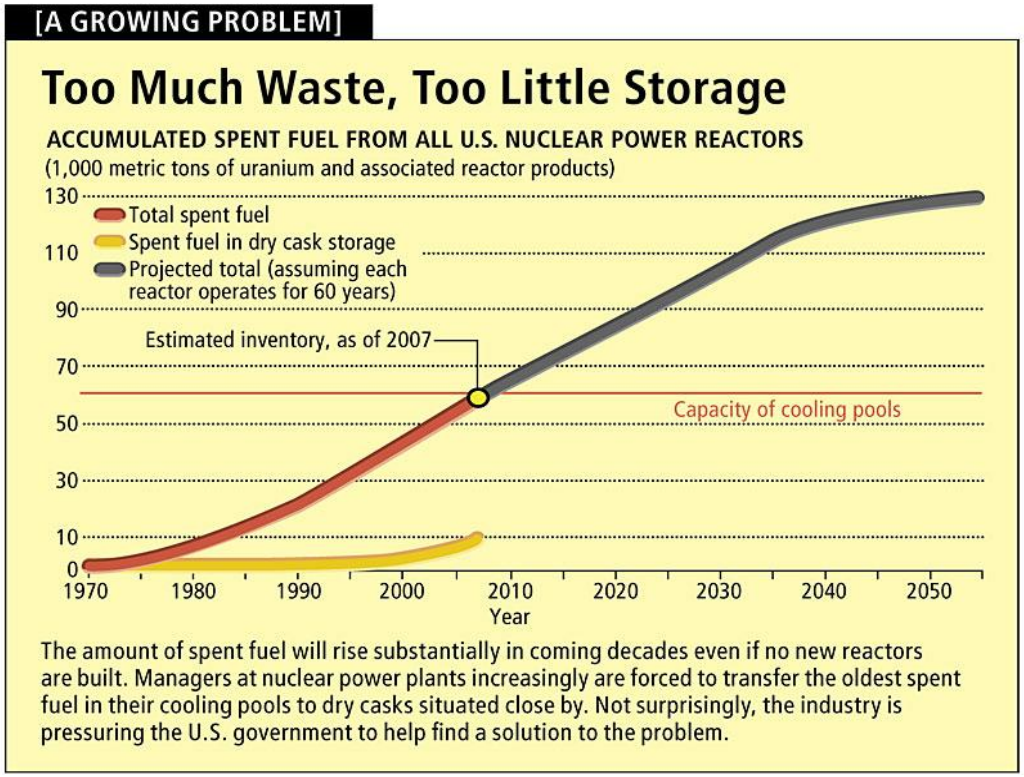


Nuclear Waste

All of the nuclear power plants in the United States together produce about **2,000 metric tons* per year of HLW**. *Source: USEPA*

Current estimate of spent nuclear fuel in the US: 90,000 metric tons (2022 estimate). *Source: US Dept. of Energy, 2023*

While HLW is a small volume of waste, it is arguably the most toxic of all wastes. Further HLW remains radioactive at levels affecting human health for at least 250,000 years.



* A metric ton (tonne) is equal to 1000 kilograms or 2,200 pounds. For our conversation, metric tons and English tons will be considered equivalent.

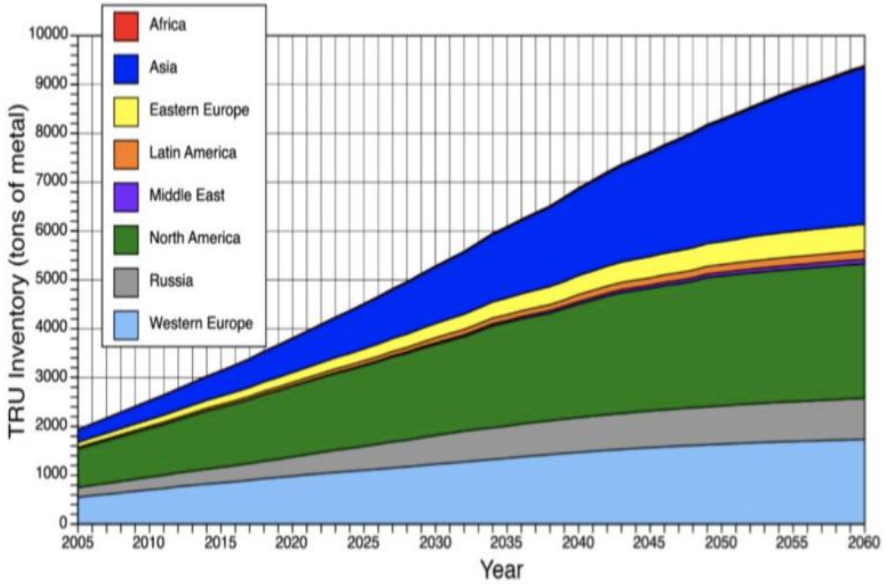
Nuclear Waste

Worldwide:

- Nuclear power plants generate about 10,000 metric tons of HLW per year and this number will increase as additional power plants come on-line.
- It is estimated (2026) that 450,000 metric tonnes of HLW are present. These masses will increase as additional power plants come on-line.
- As with the US, the majority of this waste is in temporary storage (e.g., on-site).
- The majority of *future HLW* will come from Asia.

The world's inventory of long-lived, highly radioactive nuclear waste (transuranic elements or TRU), in tons.

TRU are a small part of total radioactive waste, but their long lived toxicity - more than 200,000 years - render their them particularly difficult to dispose of. Below are projections to 2060, assuming the present number (450) of nuclear power plants and those expected to be commissioned (58) by 2035. Highly radioactive waste will exceed 9000 tons by 2060.



Solid Waste: “e” wastes



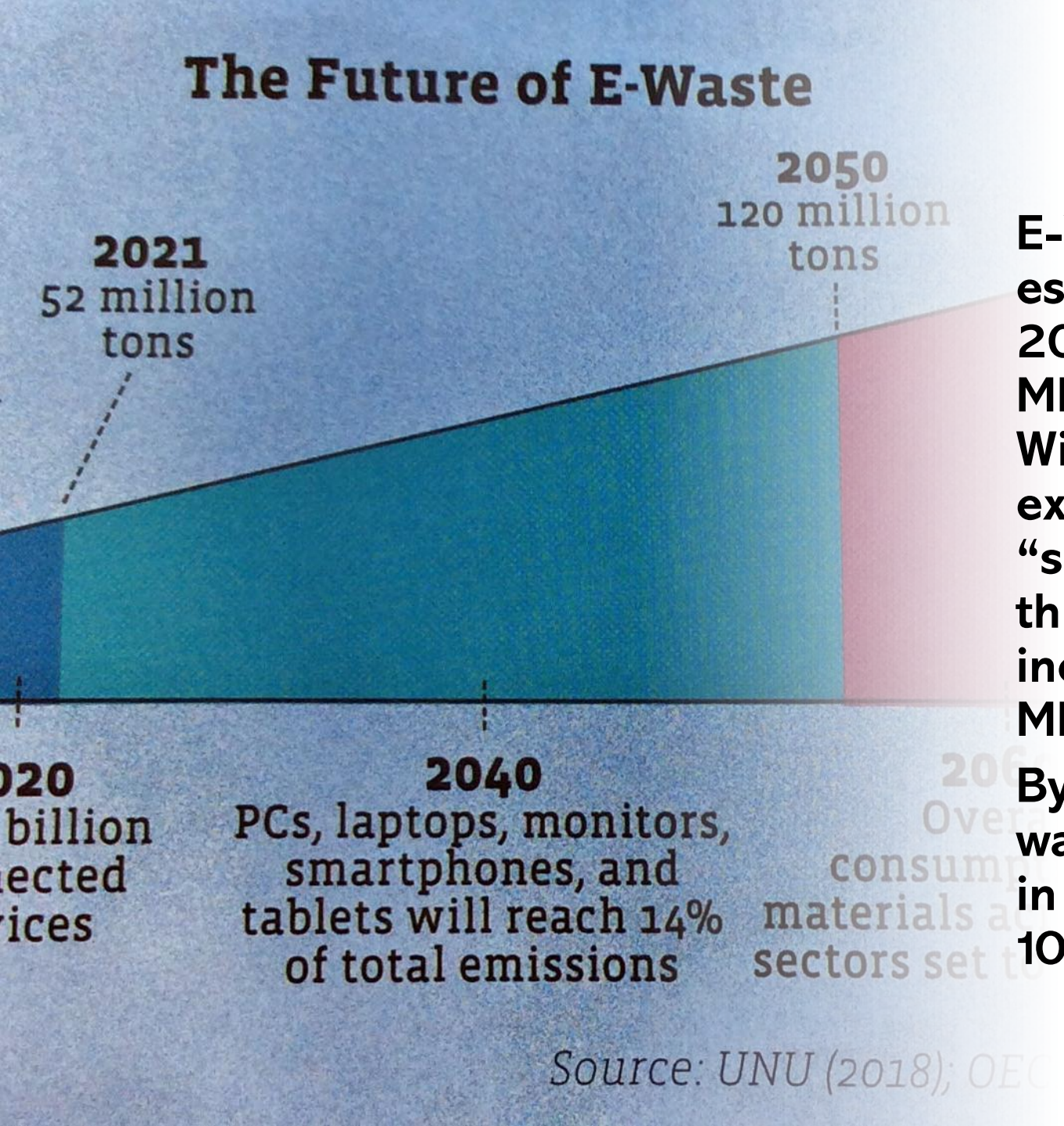
- E-waste or electronic waste is created when an electronic product is discarded after the end of its useful life. **“Useful life” is determined often through consumer “wants”, not functionality.**
- The rapid expansion of technology and the consumption driven society results in daily generation of significant quantities of E-waste.
- The integration of electronic components into heretofore “dumb” appliances is a dynamic that will increase E-waste generation.

E-Wastes

The UN Environment Program defines e-waste as any electrical or electronic equipment that has been discarded. This includes working and broken items that people throw in the garbage or donate.

The most common example of e-waste include: microwaves, cell phones, tablets, home entertainment appliances, televisions, video games, printers, and cords and cables. As appliances become “smarter”, waste white goods such as washing machines become, in part, e-waste.



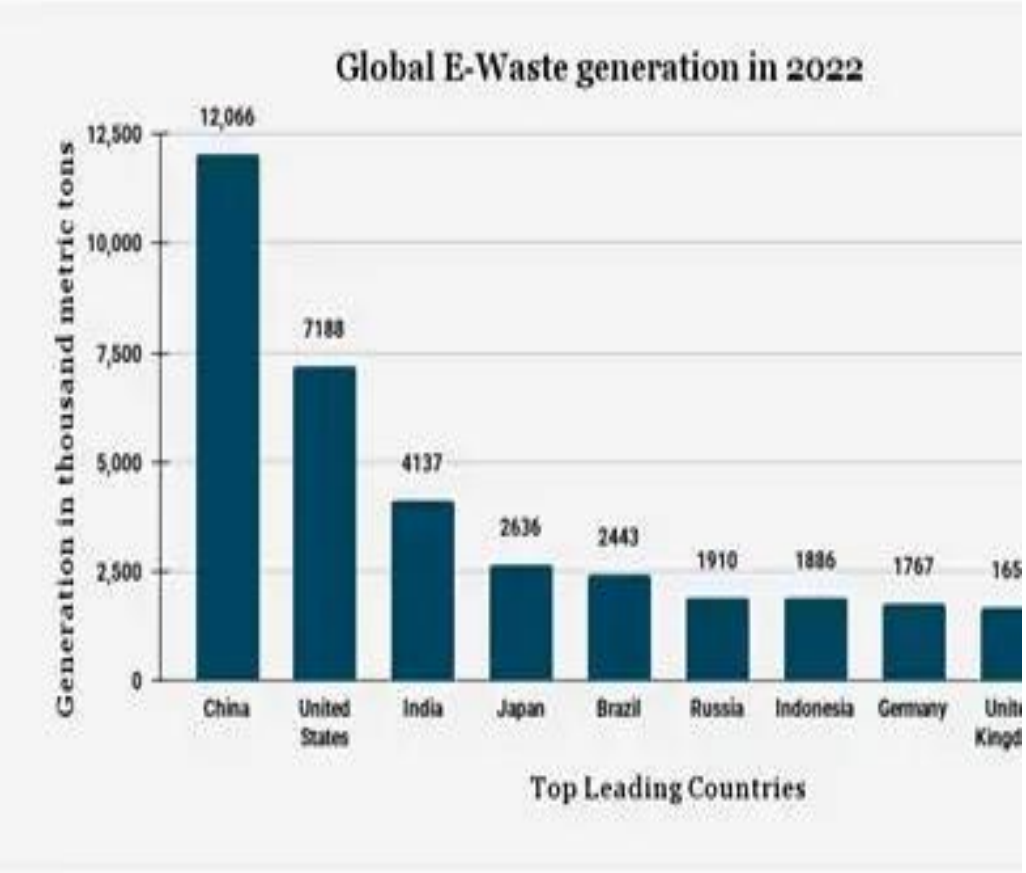


E-Waste was estimated in 2006 as a 30 MMT problem. With the expansion of “smart” devices, this volume increased to 62 MMT in 2022.

By 2050, this waste pile will be in the range of 100-120 MMT.

E-Wastes in the World

The United States and China (collectively) produced over 19 MMT of e-waste in 2022. This represents almost 30% of all e-waste generated worldwide. The greatest rate of increase in e-waste is in India, increasing from 0.3 million tonnes in 2007 to over 4.1 MMT in 2022.





E-Wastes in the World

Part of the problem surrounding e-waste is securing accurate data. Between 15- 30 billion cell phones have been manufactured since 1979; the total number of active cell phones in the world range between 8.3-8.5 billion.

There is an estimated 600 million unused cell phones in the US and around 5 billion unused phones worldwide.

Less than 20% of all discarded cell phones are recycled in some way.

E-Waste of the Future: EV Batteries

One in four vehicles sold worldwide in 2024 was an EV, totaling 17.5 million vehicles. Goldman Sachs predicts that 73million EVs will be sold worldwide in 2040 and that over 700 million EVs will be on the roads at that time.

Each one, unless technology changes dramatically, will contain a battery with an effective lifespan of 20 years.

All of which is to say that thousands of batteries are being disposed of today and this will increase to millions of batteries in the coming decades.

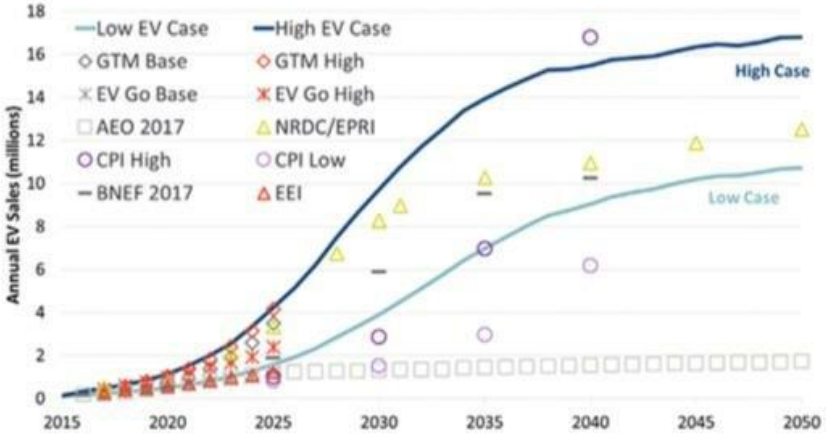


Fig. 2. U.S. EV sales projections.

Other Wastes

And then there is:

- Medical waste
- Asbestos and lead paint wastes
- Contaminated soils from remediation projects
- Discarded asphalt and other road construction wastes
- Litter including discarded medical waste



Photo shows discarded medical waste on Ocean City Beach, MD (2024)

Conclusions

8.4 pounds of waste is generated every day for every person on the planet. As affluence increases, the total and per capita volumes of waste are anticipated to increase.

"Waste" is considered an extension of the production of goods and service and, as such, has become considered an inevitable consequence of modernity.

But we, the consumer, have influence on this process and therefore can be the catalyst for change/reduction.

While possibly extreme, is it possible to **live in a society that produces Zero Waste?**



Conclusions

Most waste (whether solid, hazardous or e-waste) generated in developing nations (India is shown below) is incompletely or improperly collected. This represents the majority of waste generated today andan even larger percentage in the future.

Future waste management must expand waste collection programs.



Conclusions

A substantial percentage (upwards of 85%) of household wastes can be diverted from end-of-life facilities (e.g., incinerators) but such efforts require:

- Changes in consumer sentiment
- Economic pressures
- Governmental intervention

Recycling is often presented as a solution to waste generation but recycling is a post-generation management tool, not a reduction tool.

