



# Interactions among Circular Economies

Prof. Don Fullerton

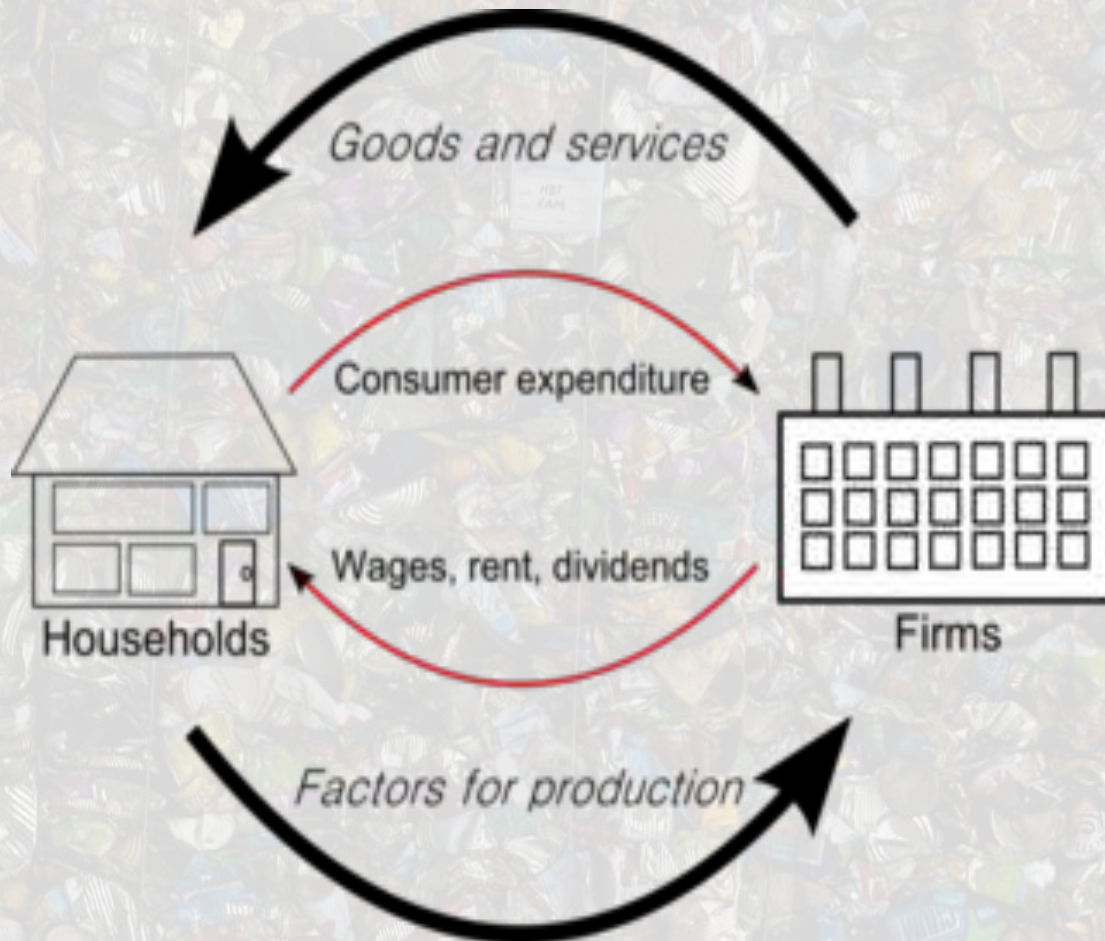
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June, 2018



# I'm honored to be here

- Thanks for the invitation, and for all the help getting here!
- The “Circular Economy”?
- I am no expert on E.U. recycling, so I'll focus on concepts: how to think about policy options.
- First, an economist might think that ANY economy is circular:

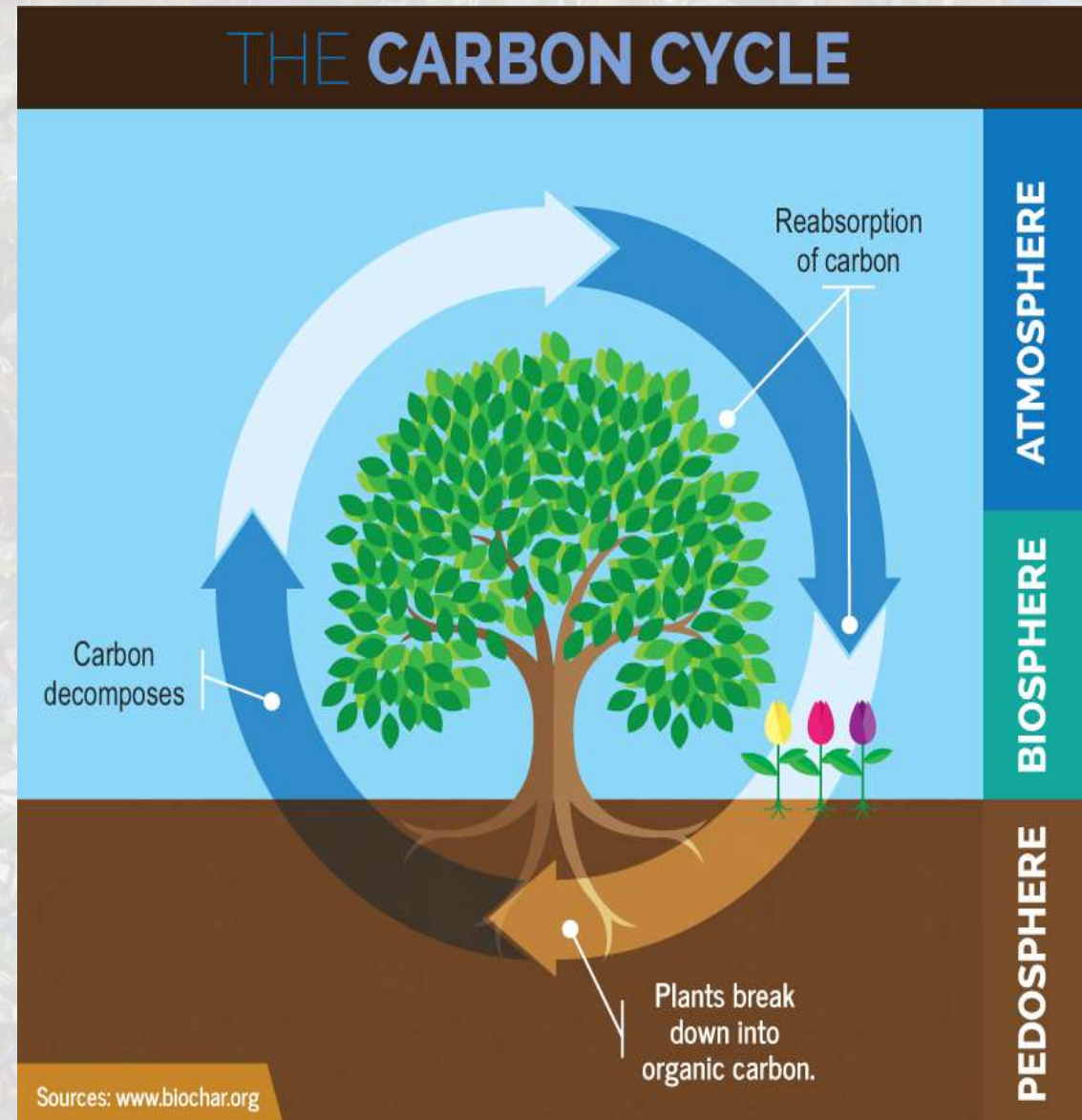




And, an *environmental* economist ...

... is also familiar with the “carbon cycle,” related to climate change.

- Before the industrial revolution, that system was in “equilibrium” – an economic concept!
- But no, that’s not “*the*” circular economy either!

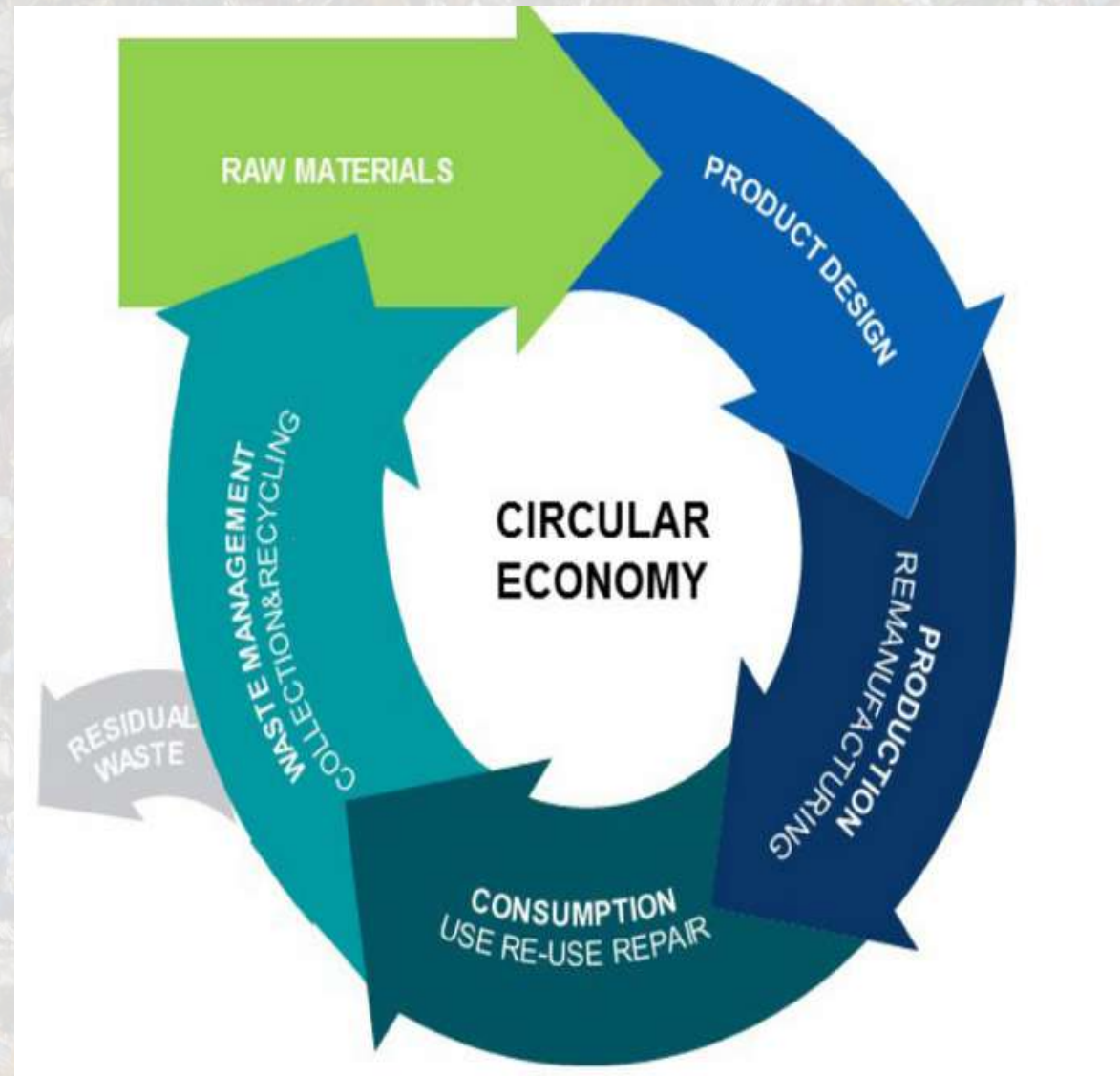




# Rather, *the* “Circular Economy” ...

... is the *waste* cycle!

- Oh, okay.
  - “Policies for Green Design”
  - “Garbage, Recycling, and Illicit Dumping”
  - “Household Responses to Pricing Garbage by the Bag”
  - “Two Generalizations of a Deposit-Refund System”





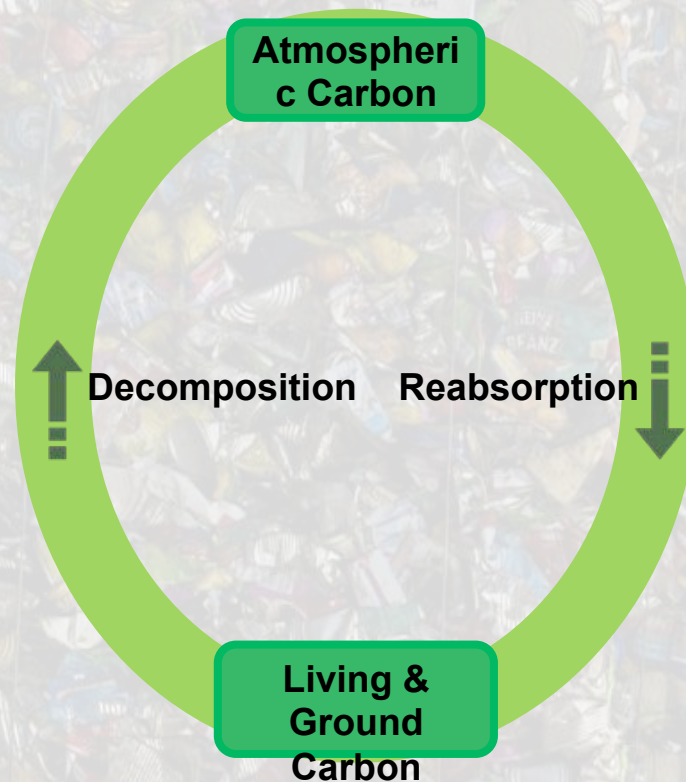
# But by that time, I'm already thinking about *Multiple Cycles* and their Interactions

- Outline:
  1. The Carbon Cycle
  2. The Production-Consumption Cycle
  3. Government's Role
  4. Air Pollution
  5. Solid Waste
  6. Policies to Achieve and Maintain **Balance**



# The Carbon Cycle

- With no human interference, the natural cycle was in relative **balance** for millennia
- 210 GtC (gigatons of carbon) per year into and out of the atmosphere





# Meet Svante Arrhenius, Swedish Scientist



THE  
LONDON, EDINBURGH, AND DUBLIN  
PHILOSOPHICAL MAGAZINE  
AND  
JOURNAL OF SCIENCE.

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS \*.

I. *Introduction: Observations of Langley on Atmospheric Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long

maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was

elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to  $-200^{\circ}$  C., if that atmosphere did not possess the quality of selective

\* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.

† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).

‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.

§ *Comptes rendus*, t. vii. p. 41 (1838).

*Phil. Mag.* S. 5. Vol. 41. No. 251. April 1896.

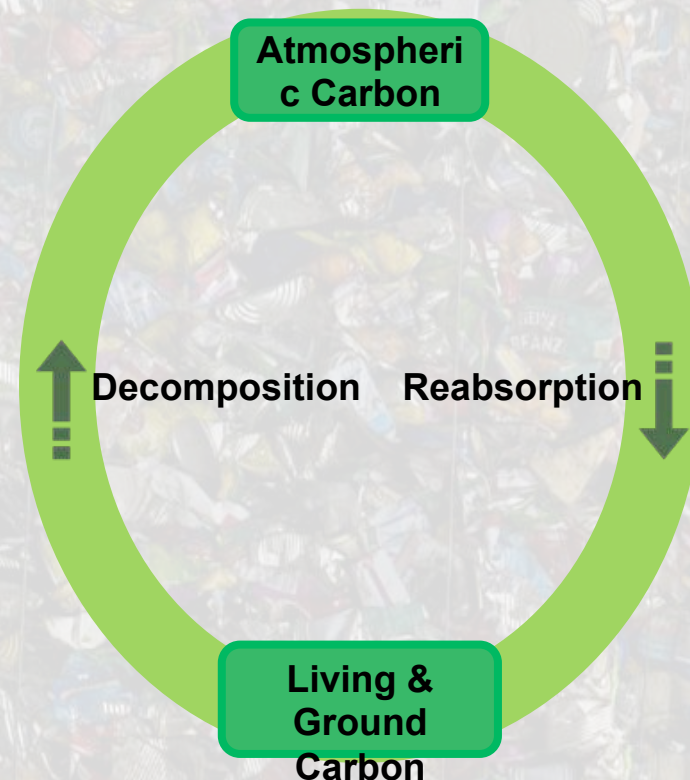
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# The Carbon Cycle

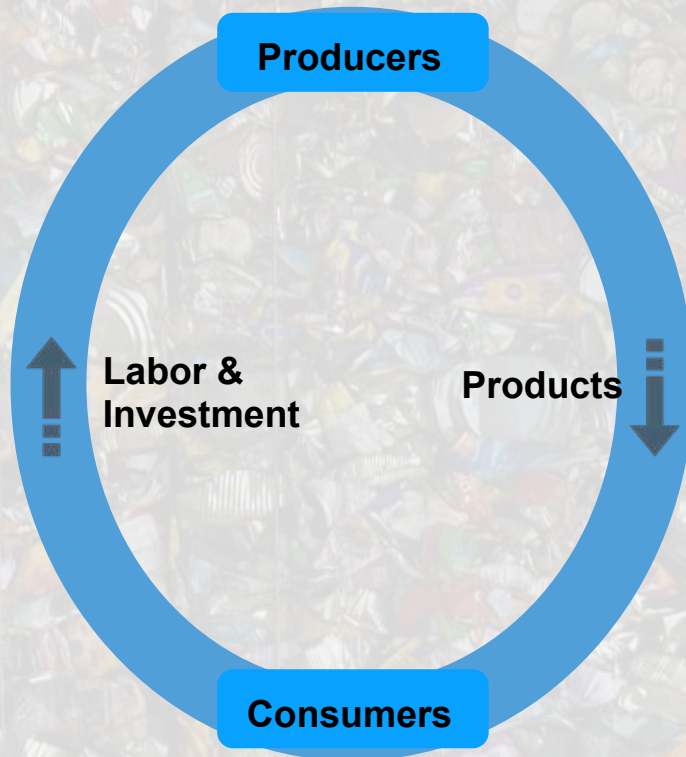
- With no human interference, the natural cycle was in relative **balance** for millennia
- 210 GtC (gigatons of carbon) per year into and out of the atmosphere
- Now, human *direct* emissions add about 9 GtC per year (4% increase)
  - Burning fossil fuel is 7.6 GtC per year
  - Deforestation & land use is 1.5 GtC
- some into oceans, some into vegetation, and almost *half* stay in atmosphere. But, ...
- Agriculture alters soil release & take-up

- Nitrogen runoff can reduce the ocean's take-up by half!
- Local air pollutants create ozone, which disrupts take-up by forests
- To restore **balance**, we need more than just a CO<sub>2</sub> emissions tax!





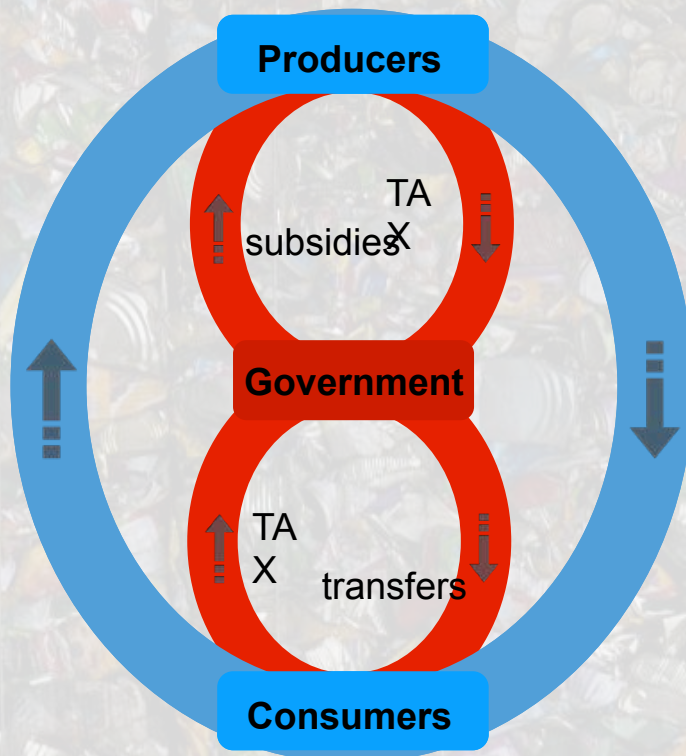
# The Production-Consumption Cycle



- For each consumer's budget to remain in **balance**, earnings from labor and capital must match spending on goods.
- For each producer to remain in **balance**, all sales revenue gets used somewhere (wages, profits, taxes).
- For any trade deficit, "**balance** of payments" requires capital inflow.



# Government

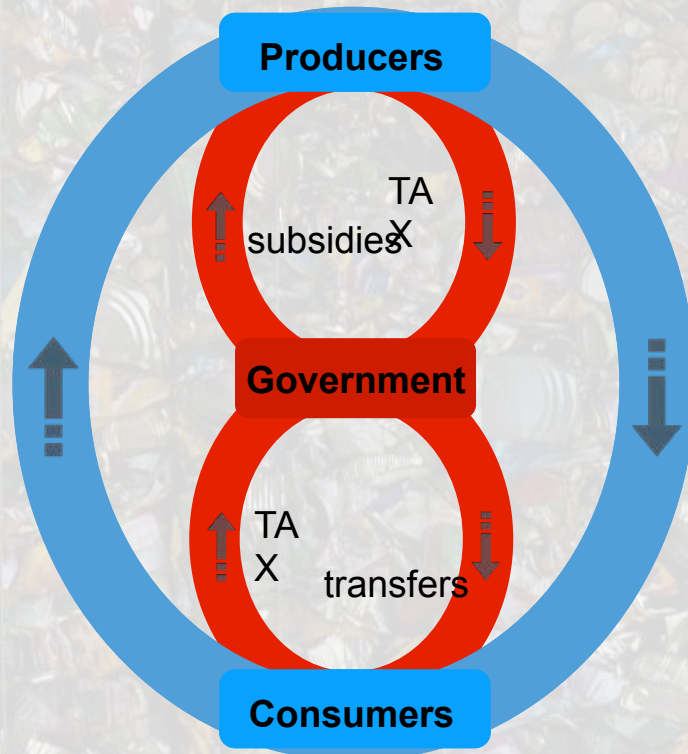


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- For each producer to remain in **balance**, all sales revenue gets used somewhere (wages, profits, taxes).
- For any trade deficit, "**balance** of payments" requires capital inflow.
- For each level of government to remain in **balance**, revenue inflow must match expenditure outflow
- Government provides public goods and can fix externalities, like air pollution.



# General Equilibrium Models

- Used to analyze and evaluate many actual or proposed policies
- Measure effects on all prices, inputs, outputs, and economic welfare



- Also feedback effects of that change on the impact of *other* policies.
- Analytical GE: aggregated models of 2 inputs, 2 outputs, 2 policies
  - Good for direction of changes, and for intuition (not detail!)
- CGE models: computable GE models of
  - Specific behaviors by many producers and consumers
  - Interactions among sectors and regions
  - Simulate numerical direction and magnitude of effects.
- Interactions among domestic taxes; international trade among nations; urban policy; environmental policy



# Air Pollution

- Local pollutants:  $\text{SO}_2$  ,  $\text{NO}_x$  particulates
  - Meuse River Valley, Belgium, 1930: 60 dead
  - Donora, Pennsylvania, 1948: 20 dead
  - Great Smog of London, 1952: 12,000 dead
  - New York City smog, 1966: 168 dead
  - Now? Rich vs. poor countries
- Global pollutants:  $\text{CO}_2$  , methane, HCFC's



**Birmingham History**

@about\_hisory

Follow



This is how polluted Birmingham was, during the Industrial Revolution.



10:35 AM - 15 Jul 2015

2 Likes

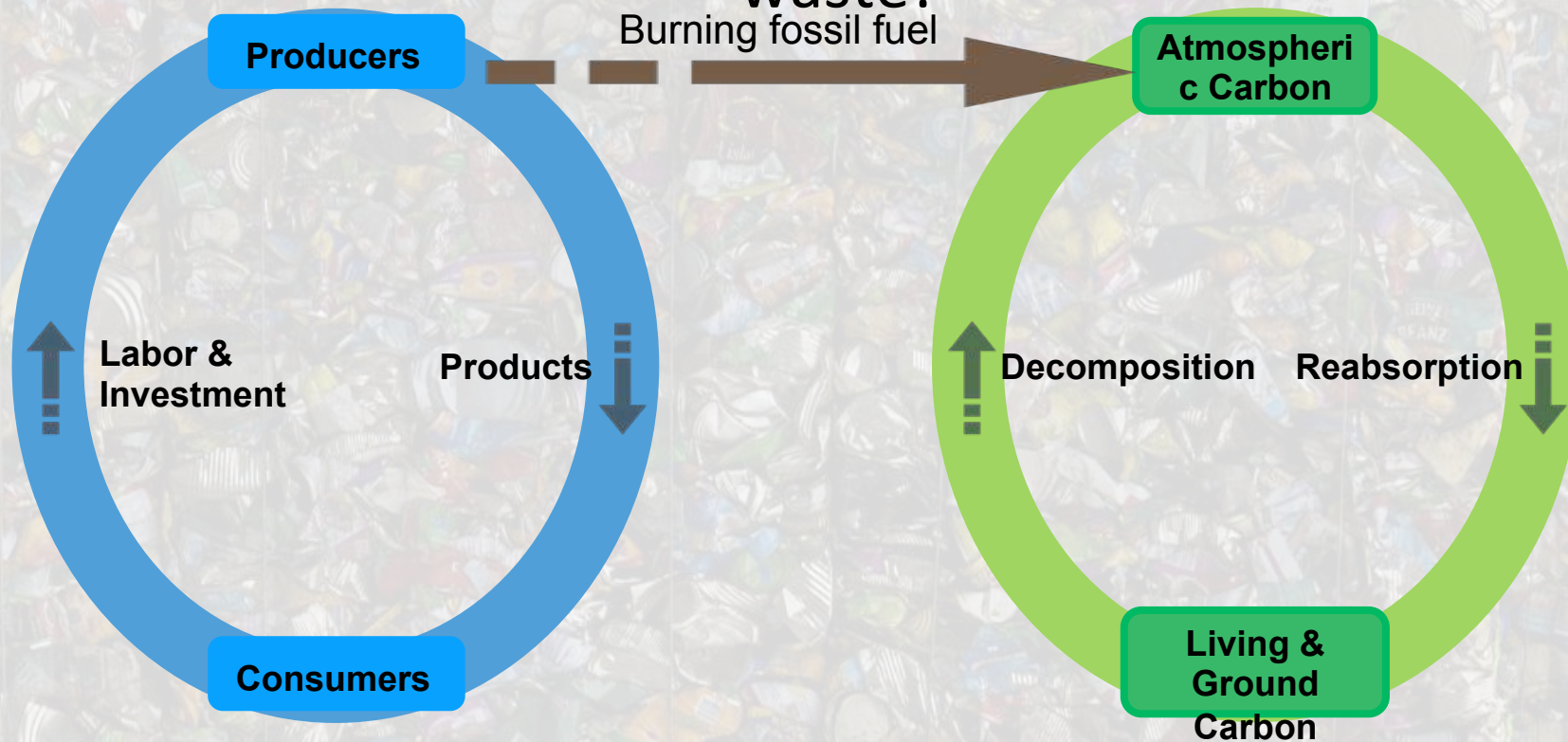




# Air Pollution

- The cycles are not independent
- Spillover from one to the other!

- But air pollution is only one form of waste
- Scrubbers convert gas waste to solid waste!

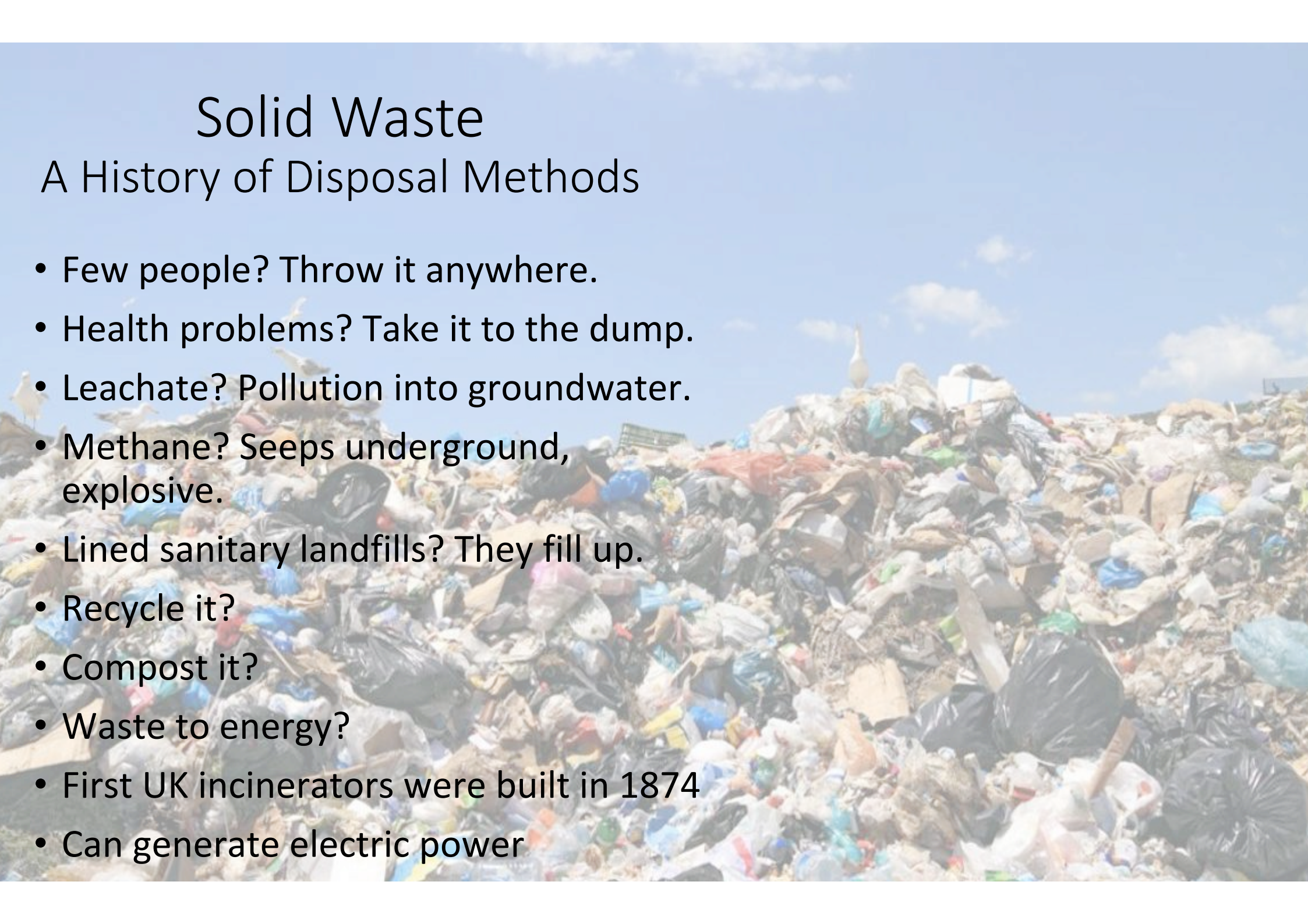




# Solid Waste

## A History of Disposal Methods

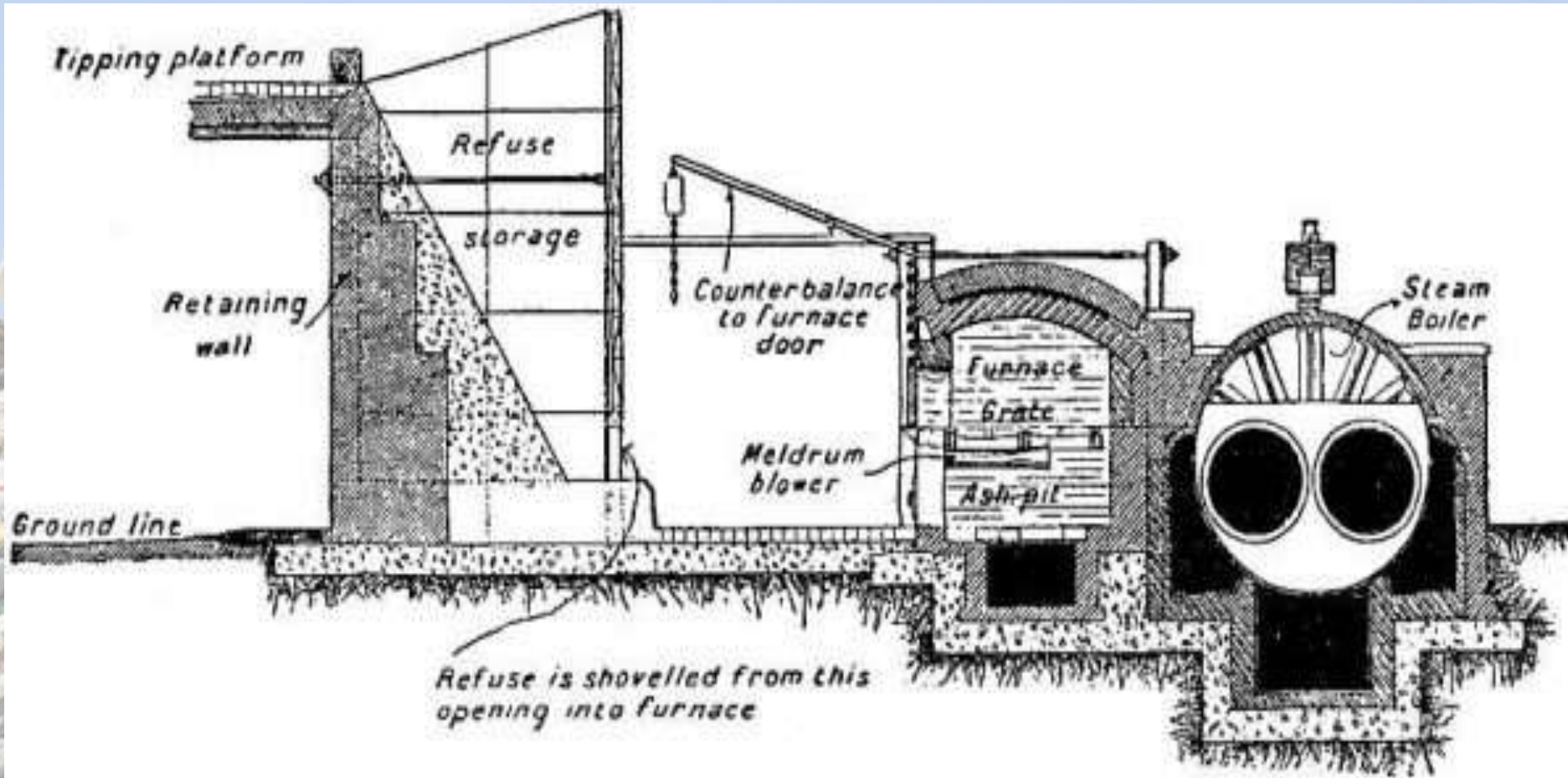
- Few people? Throw it anywhere.
- Health problems? Take it to the dump.
- Leachate? Pollution into groundwater.
- Methane? Seeps underground, explosive.
- Lined sanitary landfills? They fill up.
- Recycle it?
- Compost it?
- Waste to energy?
- First UK incinerators were built in 1874
- Can generate electric power





# Solid Waste

## History of Disposal Methods



- First UK incinerators were built in 1874
- Can generate electric power
- Produces ash and flue gas.
- Converts solid waste to gas waste.



A large pile of crushed aluminum cans, ready for recycling. The cans are flattened and mixed together, creating a dense, colorful texture of metallic silver, blue, red, and green. The text is overlaid on the center of the image.

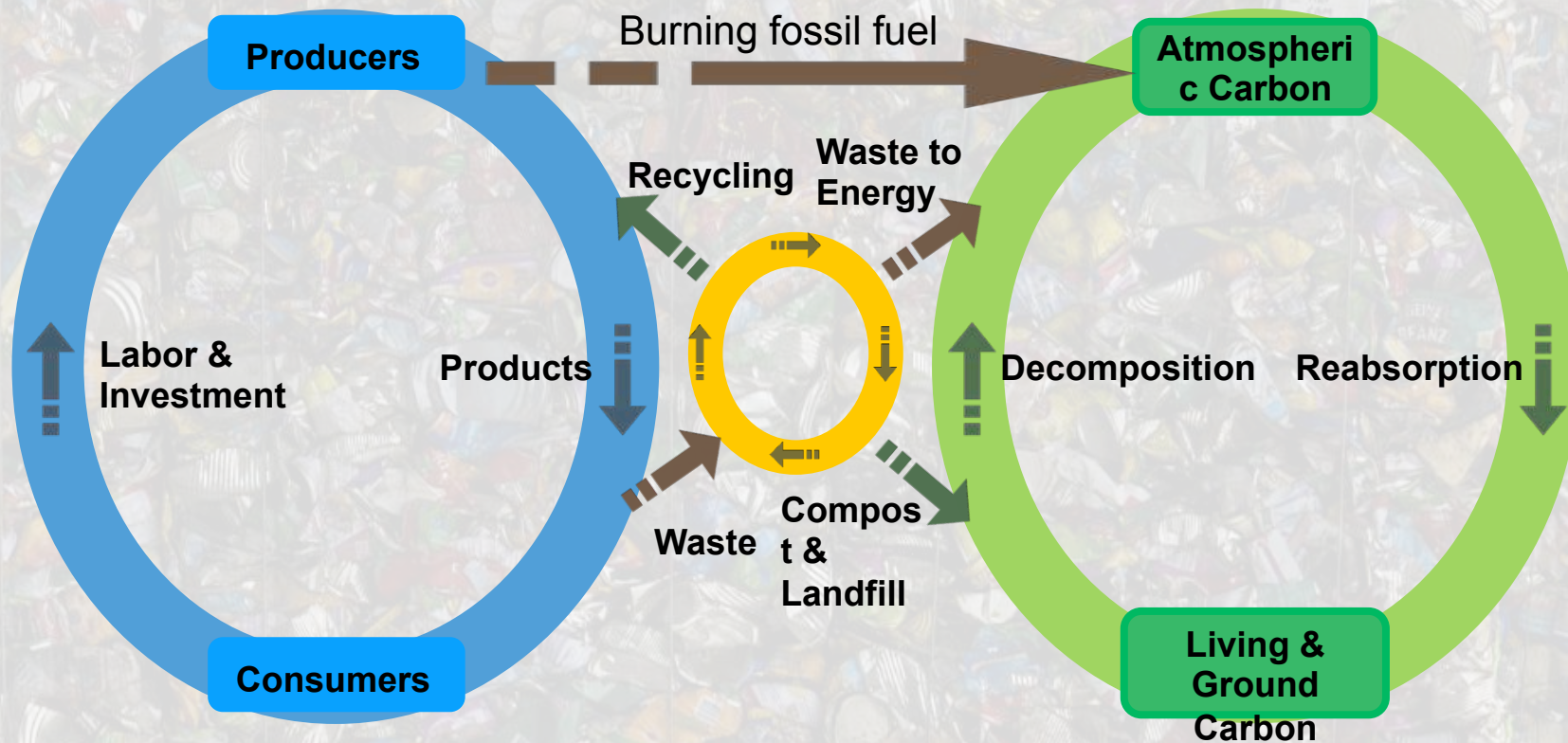
Finally, I'm ready to discuss

# Recycling



# All three cycles

- with human interference
- but humans can reestablish **balance**!



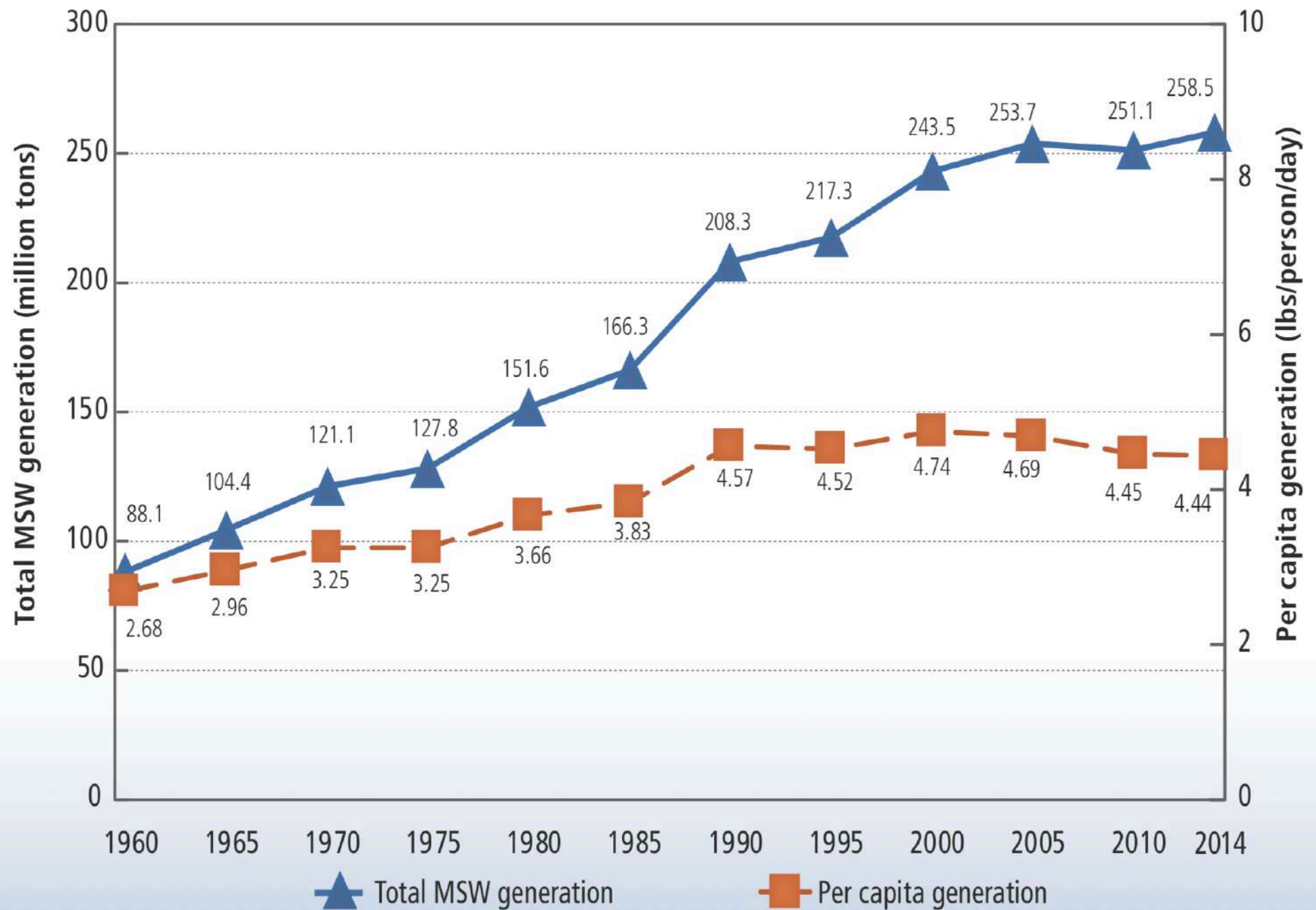


Shows  
U.S. MSW



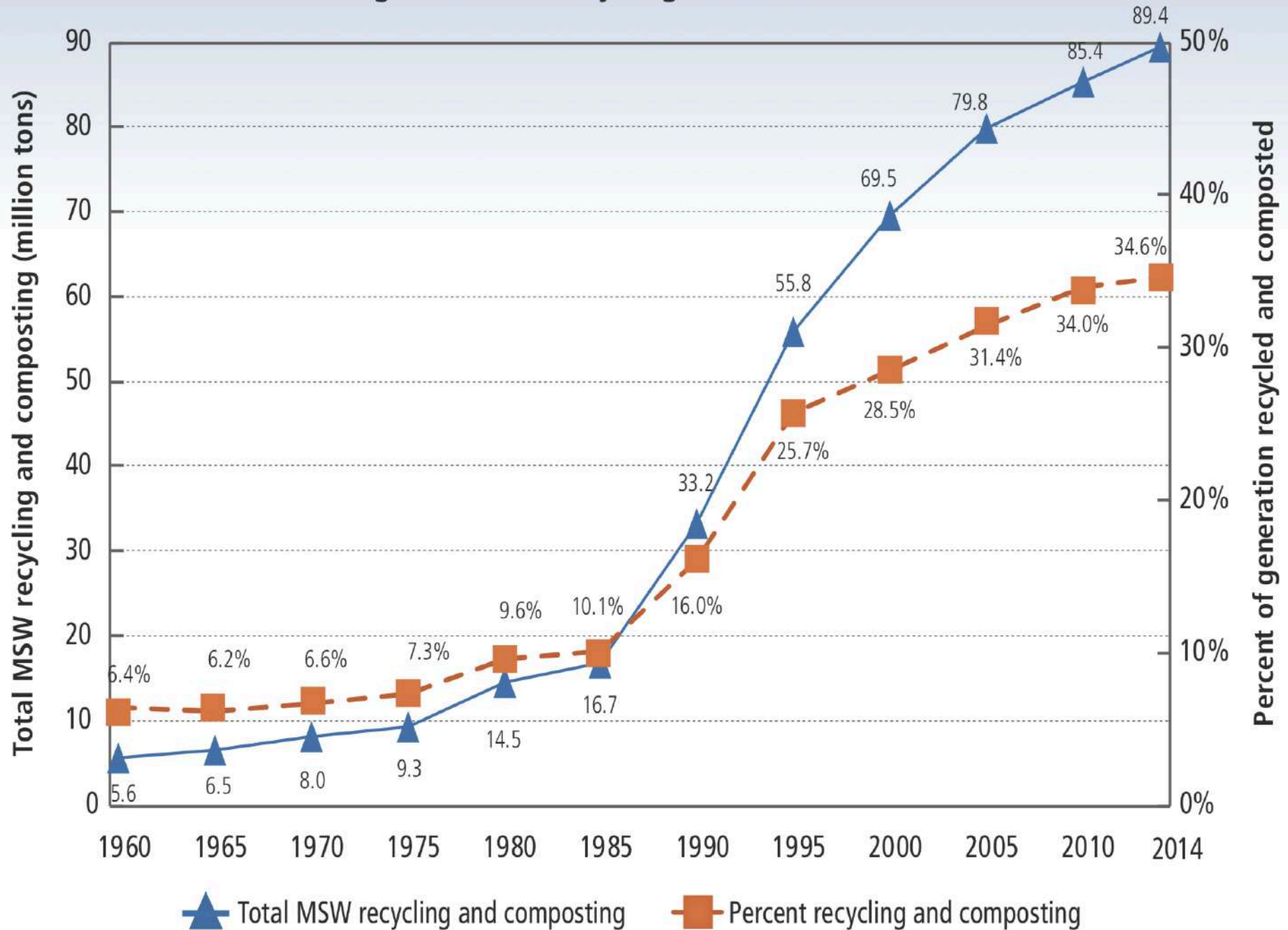


**Figure 1. MSW Generation Rates, 1960 to 2014**





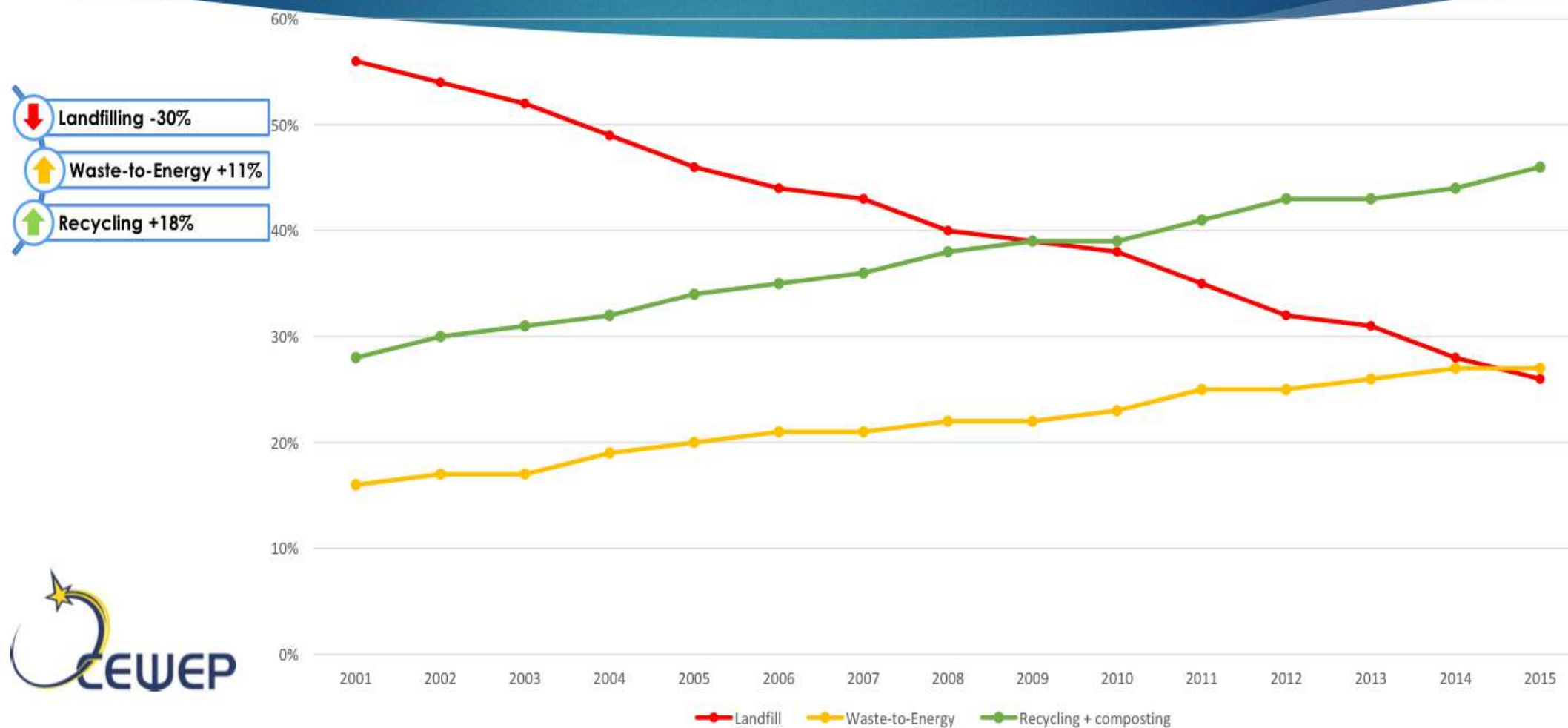
**Figure 2. MSW Recycling Rates, 1960 to 2014**





# Municipal waste treatment trends 2001-2015 EU 28

Graph by CEWEP,  
Source: EUROSTAT 2017

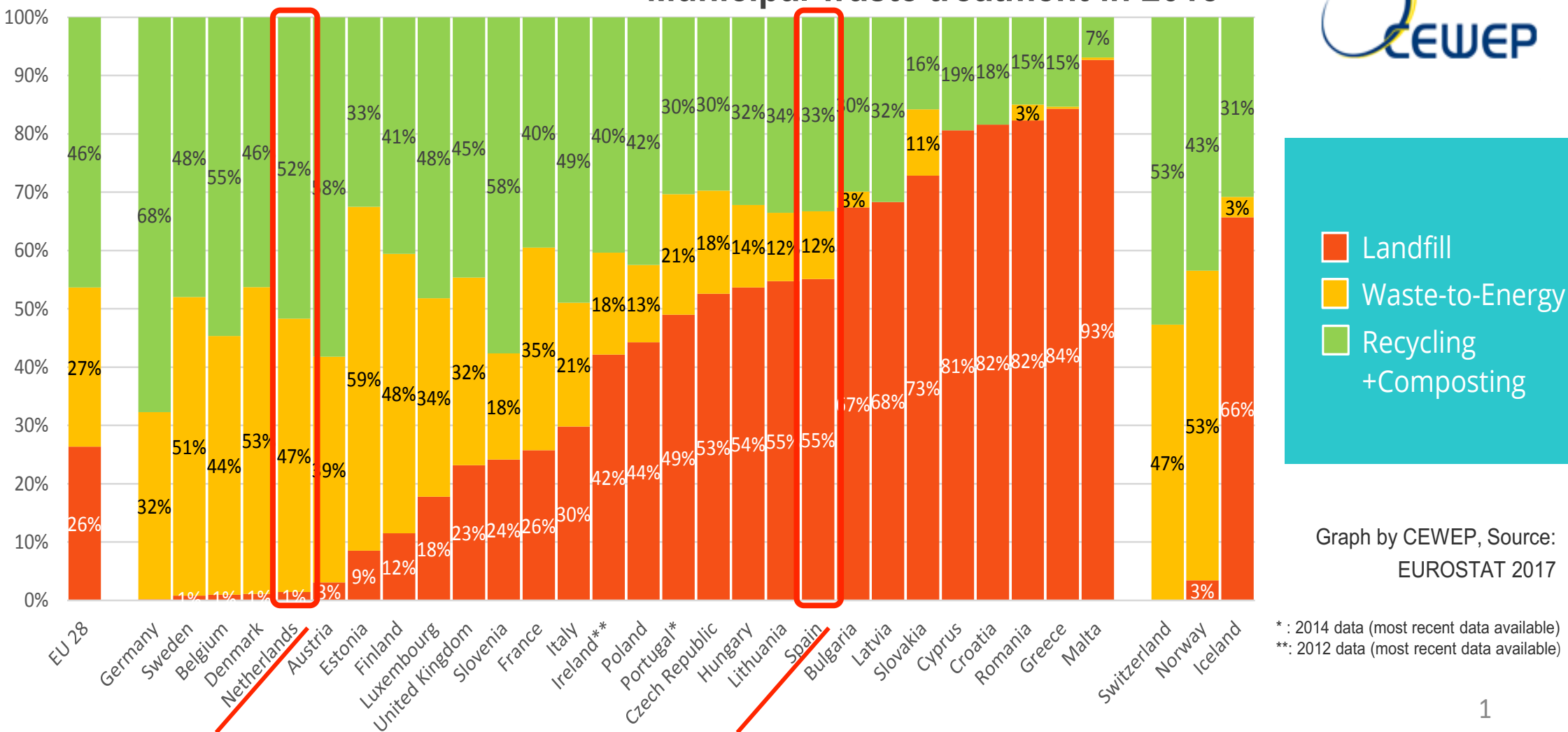






# Recycling & WtE complementary to divert waste from landfills

EU 28 + Switzerland, Norway and Iceland  
Municipal waste treatment in 2015





# Recycling

- Some stuff is valuable! (aluminum)
- Avoids ever-more landfills
- Avoids air pollution from incineration
- Avoids using up virgin materials
- Avoids use of energy for extraction
- Perhaps an “ideal” of zero landfill and zero virgin materials?

**BUT:**

- Some stuff has no recycled value
- Cost of recycling and reprocessing

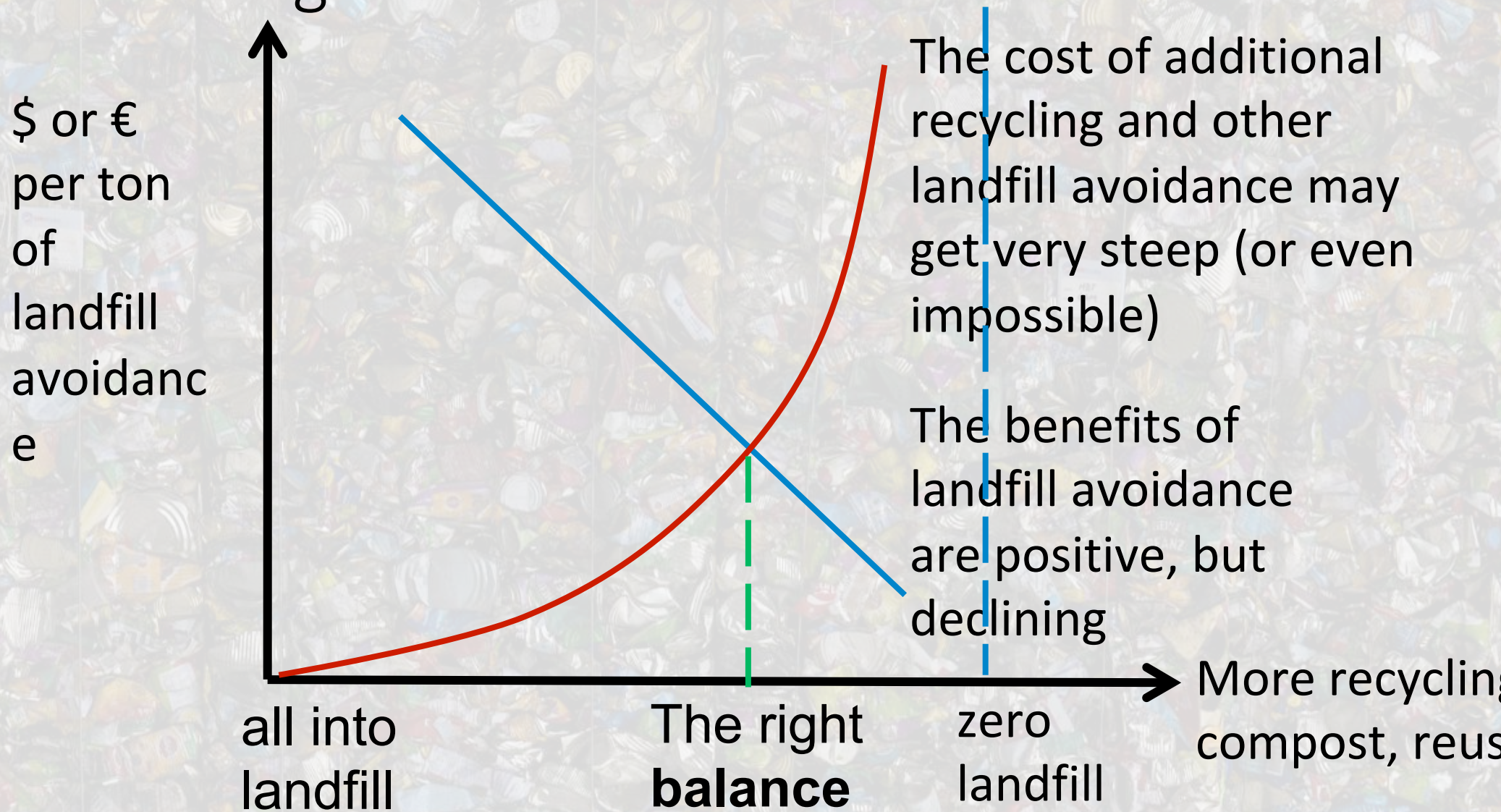
- Recycled material may cost more than raw material (so not done w/o subsidy)
- Some stuff extremely difficult to recycle



- *Some* space in landfill is cheap and easy
- Why does it need to be *zero* landfill, if that's impossible and landfill is cheap?



# My one and only economics diagram:

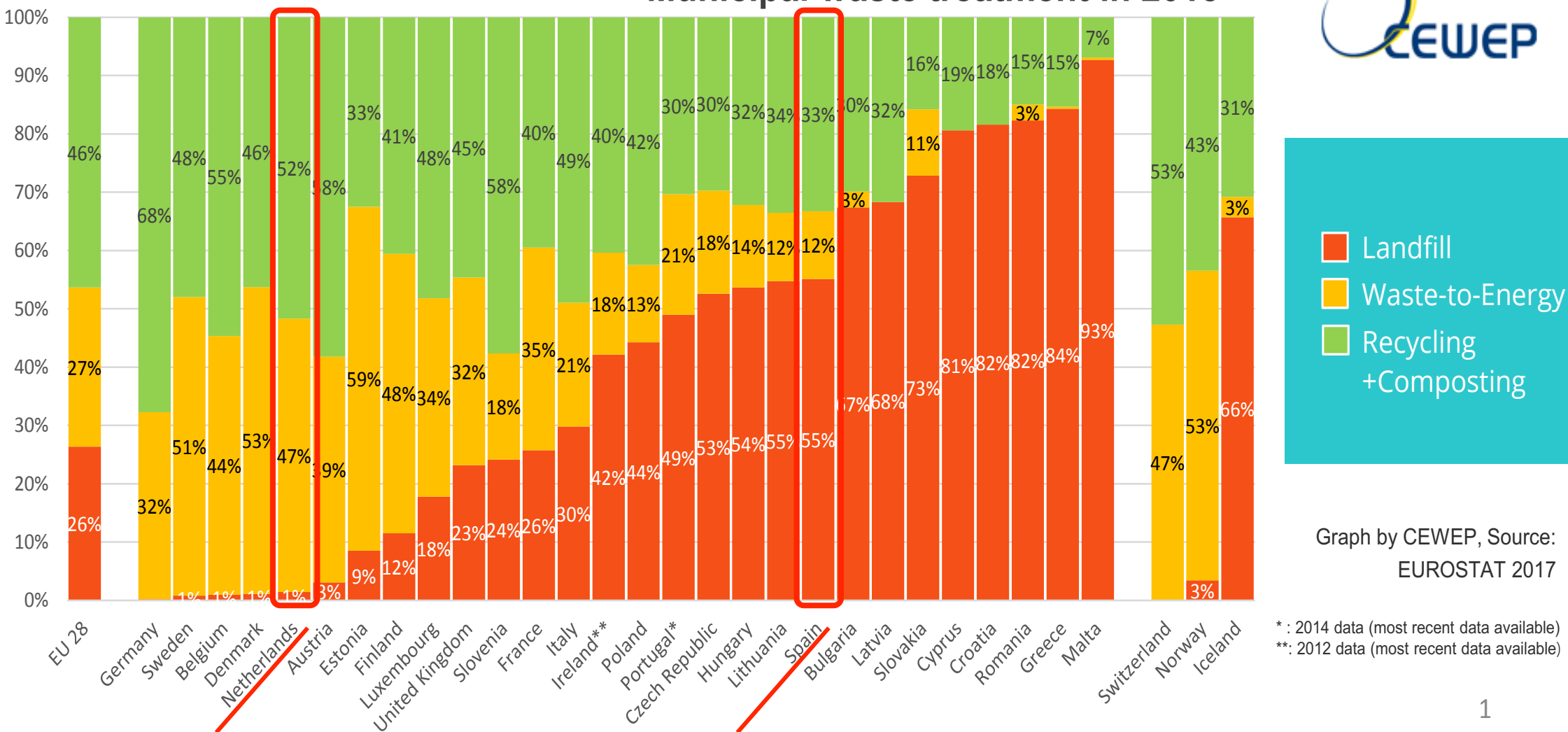






# Recycling & WtE complementary to divert waste from landfills

EU 28 + Switzerland, Norway and Iceland  
Municipal waste treatment in 2015



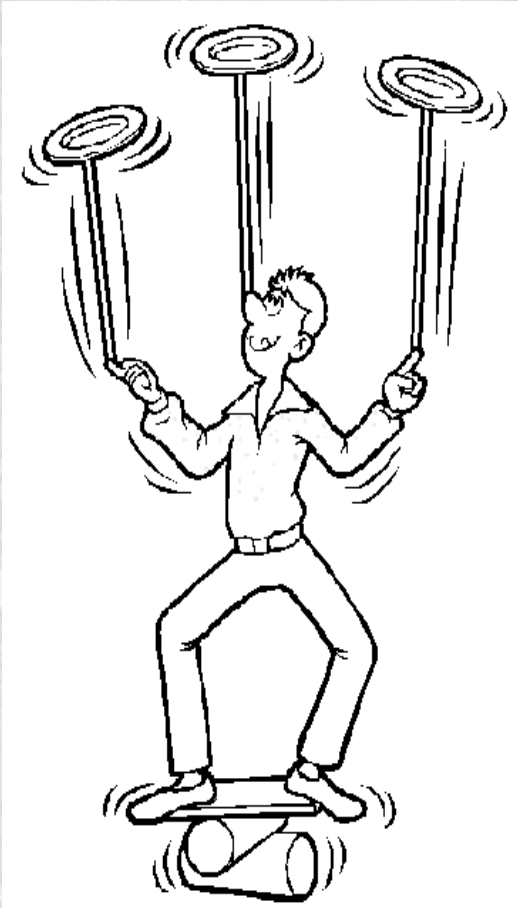
Graph by CEWEP, Source:  
EUROSTAT 2017

\* : 2014 data (most recent data available)

\*\* : 2012 data (most recent data available)



# How best to keep such **balance**?



- Most common: regulations and mandates, where political leaders try to “pick winners”
  - A. Require households to recycle?
  - B. Forbid food waste in garbage?
  - C. A new recycling plant here, or waste-to-energy there?
  - D. Ban certain kinds of plastic?
  - E. Extended producer responsibility?
- *Some* of those are good ideas, but which are best?
- A “price” for waste allows individual *choice* about how to reduce waste.
- Price per bag of garbage, permit price, tax, or subsidy.
- Deposit-refund: tax on purchase and subsidy to recycle.

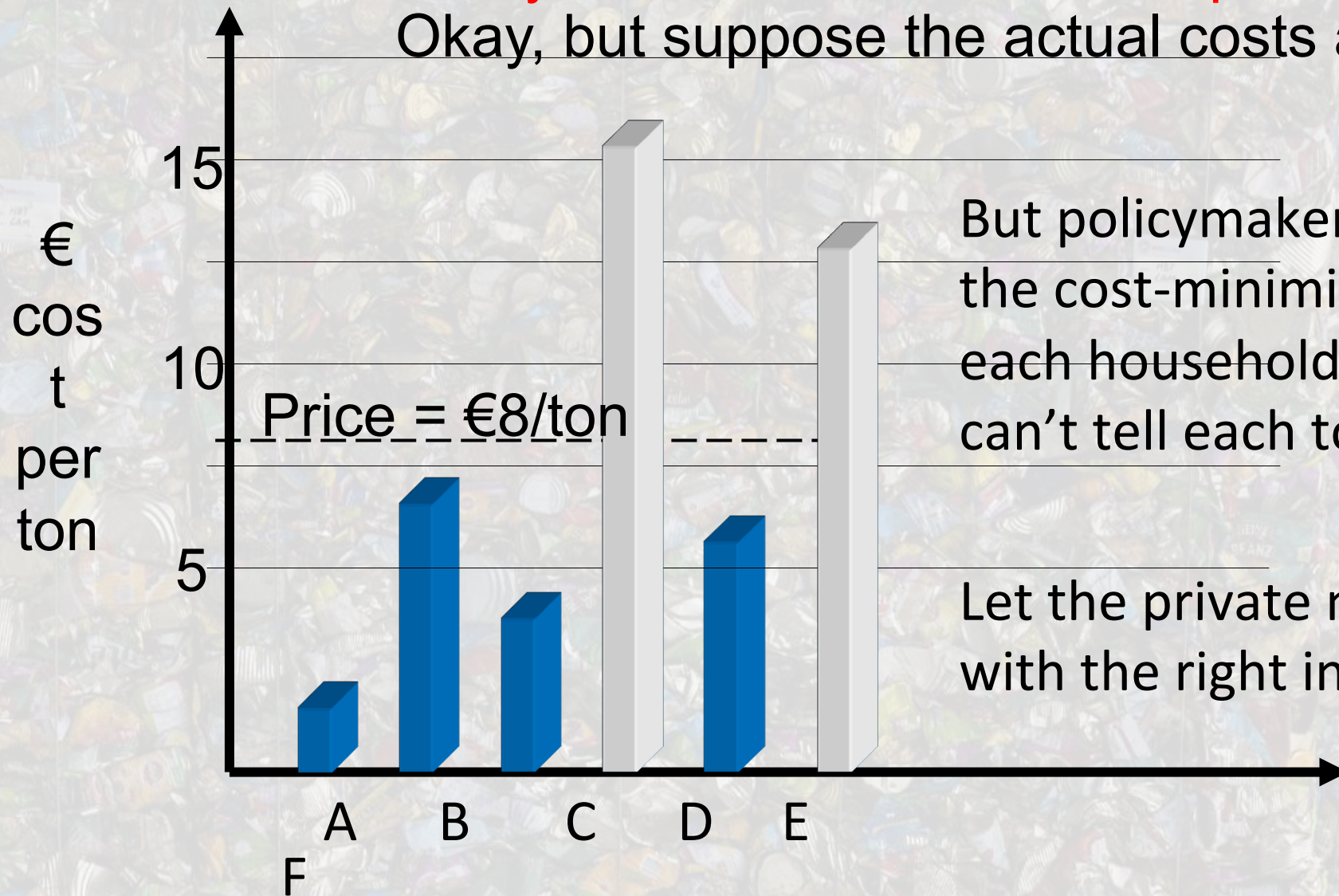


## Example:

Each project cuts waste to landfill by one million tons.

**Policymaker: "I think the best options are C and D"**

Okay, but suppose the actual costs are:



But policymakers can't know the cost-minimizing mix for each household or firm, so can't tell each to do what.

Let the private market decide with the right incentives.



## Next problem:

- Firms find it cheaper to make stuff that *can't* be recycled.
- With no price per garbage bag, households don't "demand" goods that *can* be recycled.
- *With* a price per bag, households *want* recyclable goods, but ...
- The price → illicit dumping or burning

## Need artful design of policy:

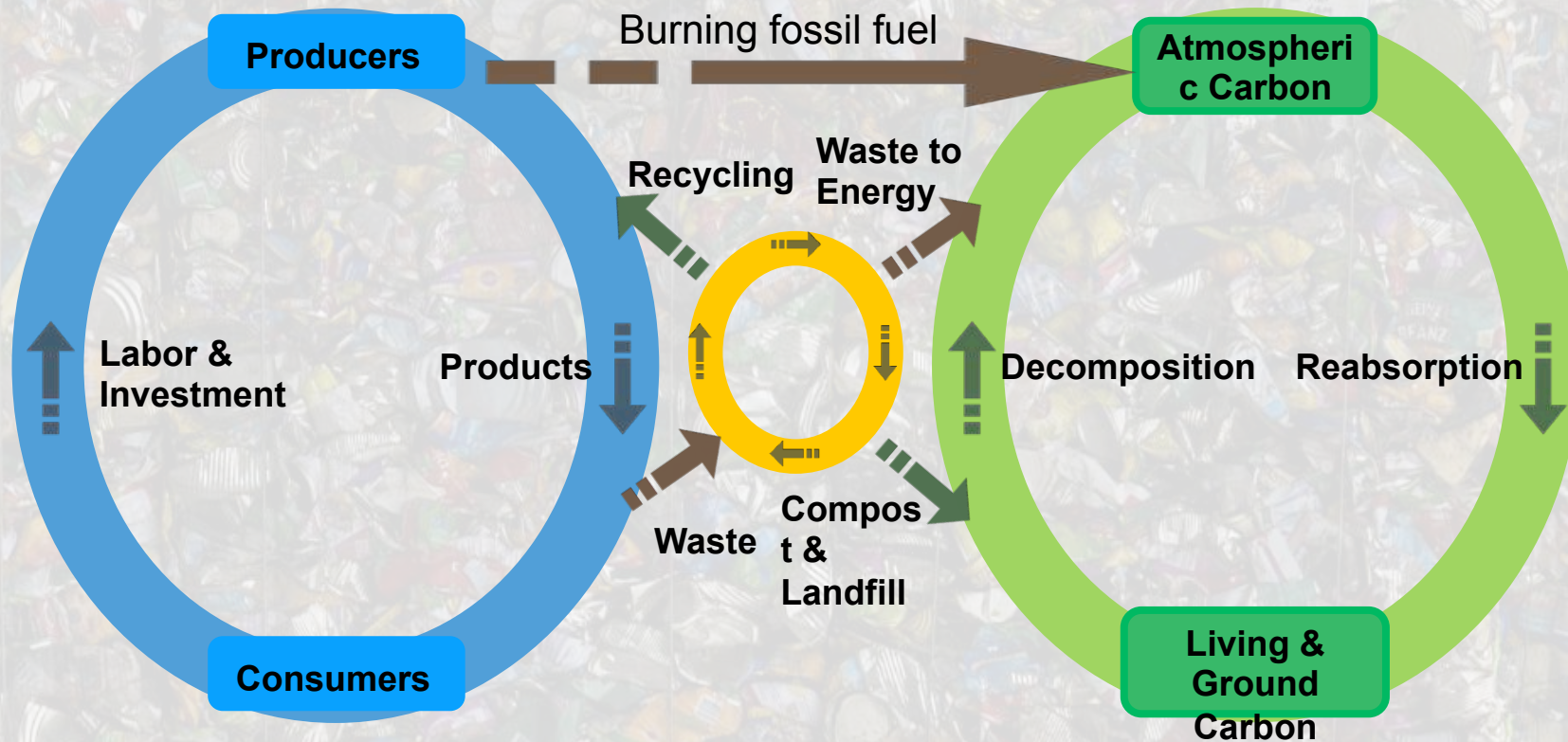
- Price per bag where families will comply
- Not so high to induce dumping
- Deposit (tax on purchase) for each item =  
social cost of *dumping* it
- Refund that amount when recycled, ...  
... leaving the tax on anything



- 
- # What is Environmental Sustainability?
- A meaningless buzzword?
  - “Leave resources as pure and unpolluted as when we got here”?
  - *Zero* use of virgin materials, and *no* use of landfills?
  - Build no roads, no dams, no buildings?
  - Not feasible. “Moral obligation” to do something that’s not feasible?
  - But, *some* use of natural resources in production and investment can leave next
  - “an obligation to conduct ourselves so that we leave to the future the option or the capacity to be as well off as we are” (Robert Solow, 1991).
  - Unspoiled nature is key to well-being
  - But can’t save every species & forest
  - Equity between generations; already they will have better technology!



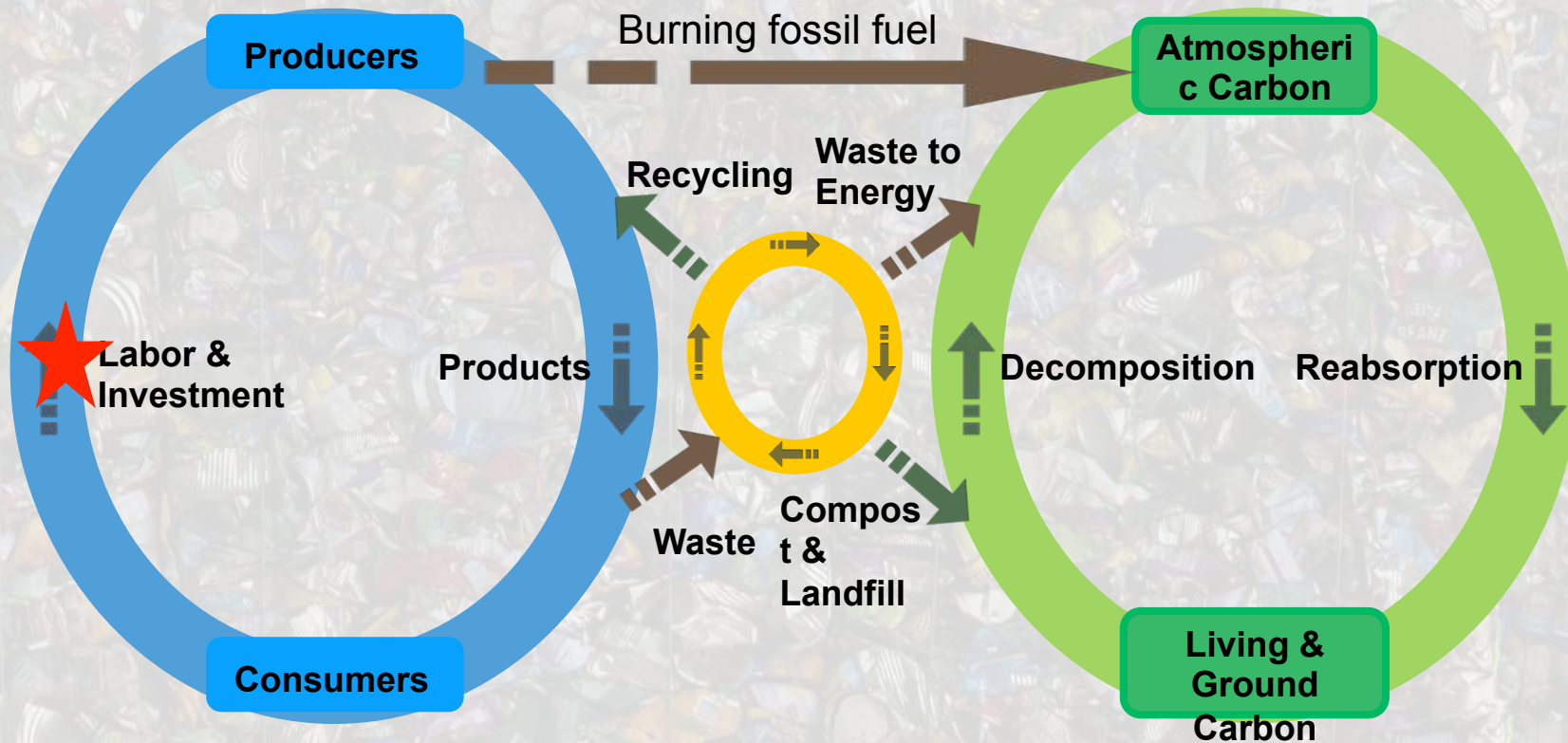
# Now: Potential policies, and interactions among the different cycles





# First: Taxes on income from labor and capital

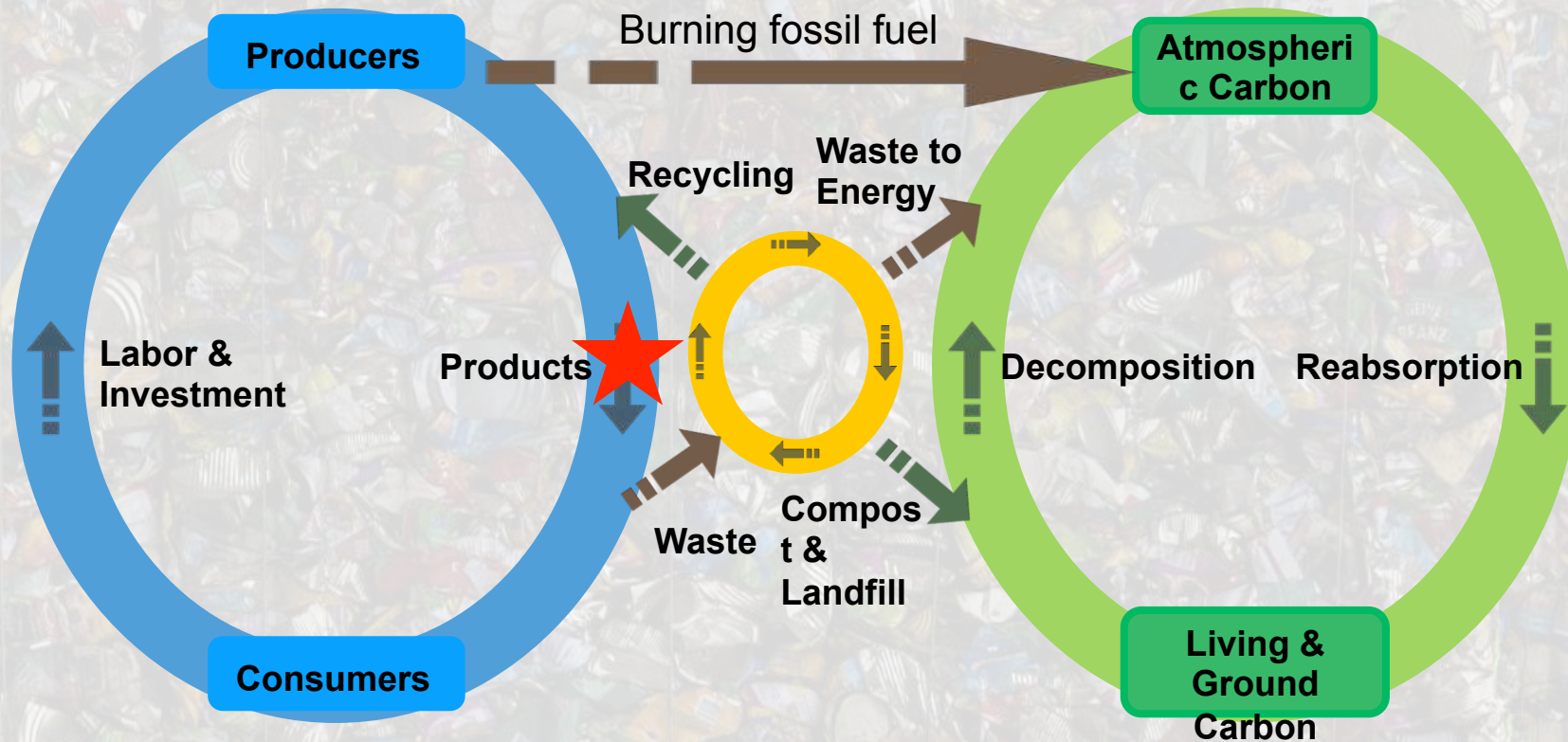
- Affect work effort, production, output, carbon emissions, and waste of all kinds.





# Taxes on products or consumption

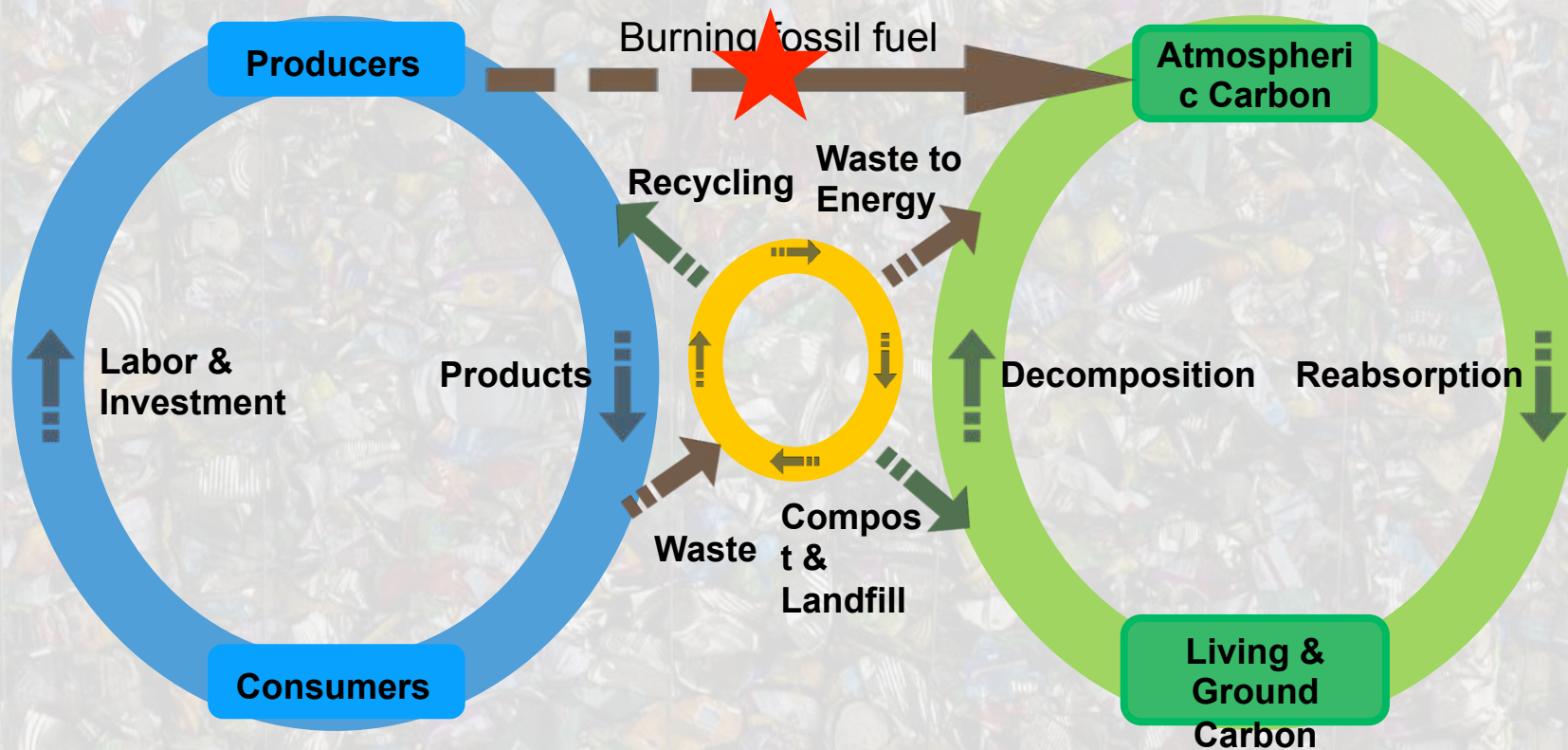
- Affect work effort, production, output, carbon emissions, and waste of all kinds.





# Taxes on pollution from burning fossil fuel

- Affect work effort, production, output, carbon emissions, and waste of all kinds.





# Air Pollution

## Global GHG:

- Carbon dioxide (CO<sub>2</sub>)
- Methane (CH<sub>4</sub>)
- Nitrous oxide (NO<sub>x</sub>)
- Chlorofluorocarbons (CFCs)
- Hydrofluorocarbons (HCFCs)

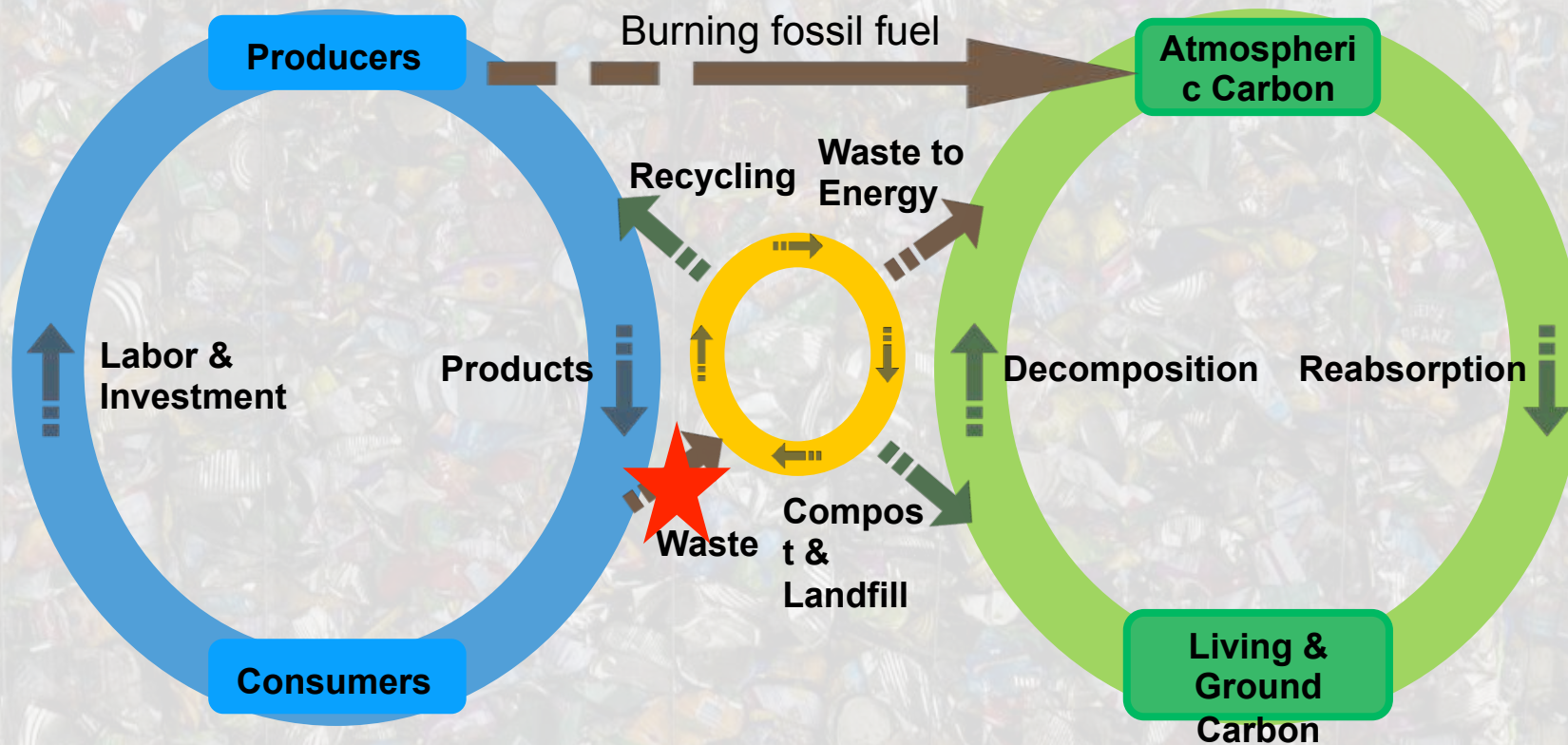
## Local:

- Particulates (PM10 & PM2.5)
- Nitrogen dioxide (NO<sub>2</sub>)
- Sulphur dioxide (SO<sub>2</sub>)
- Ground-level ozone
- Carbon monoxide (CO)



# Taxes on waste generation or collection

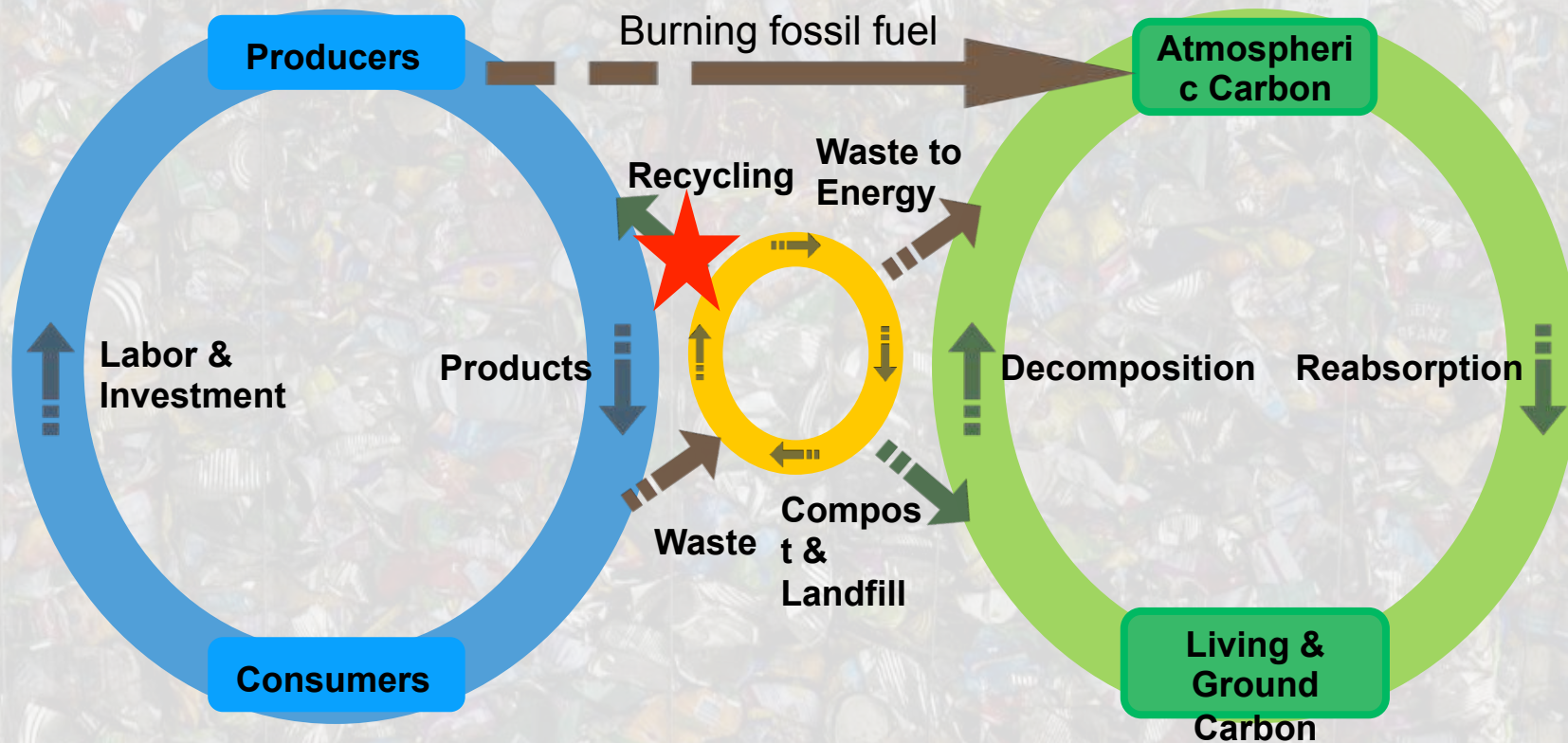
- Affect production, output, work effort, carbon emissions, and waste of all kinds.
- Can lead to litter and dumping.





# Subsidy to Recycling?

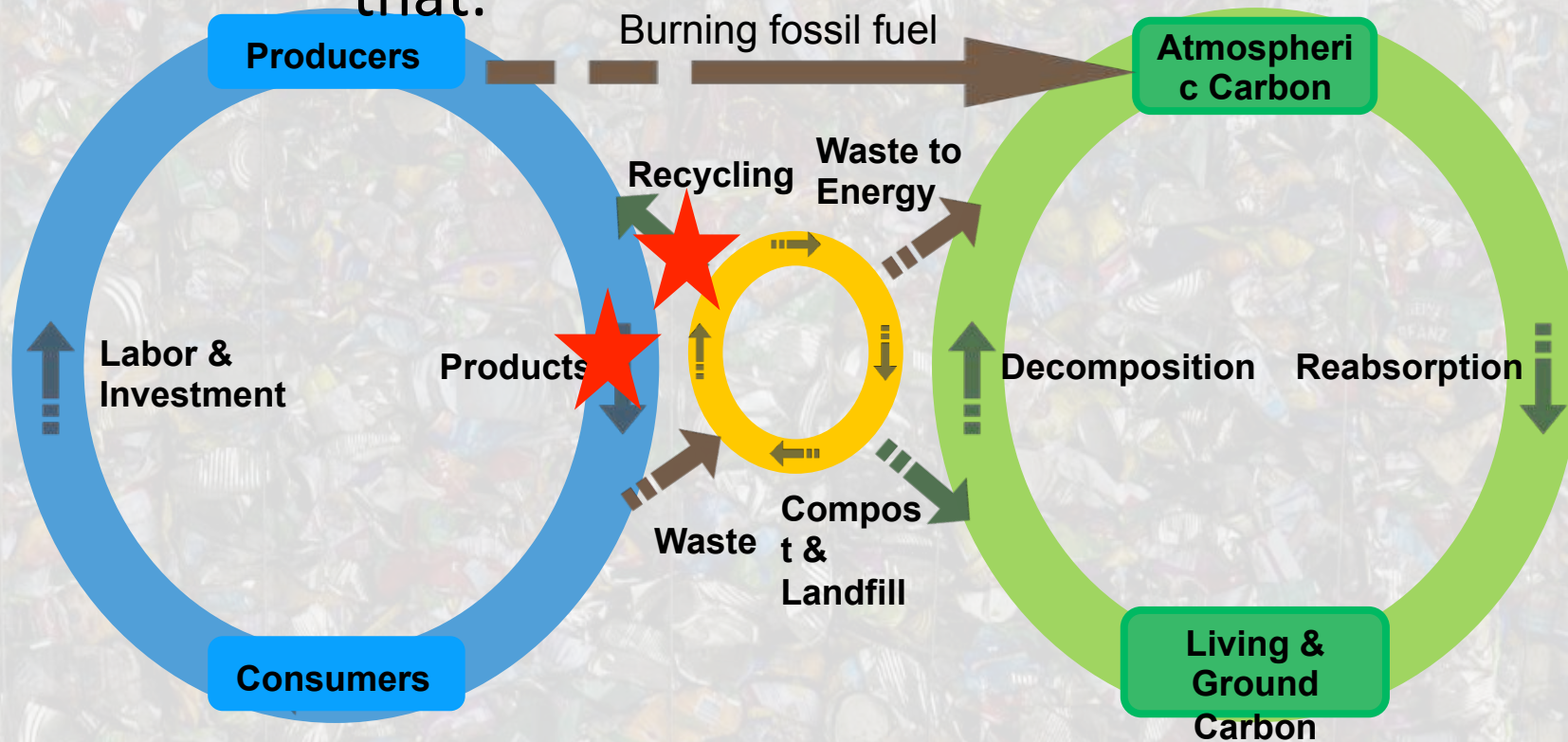
- Affect production, output, work effort, carbon emissions, and waste of all kinds.
- By itself, can generate *more* waste (for recycling).





# Try both: product tax and subsidy to recycling?

- The subsidy alone encourages waste generation (for recycling).
- The addition of product tax offsets that.





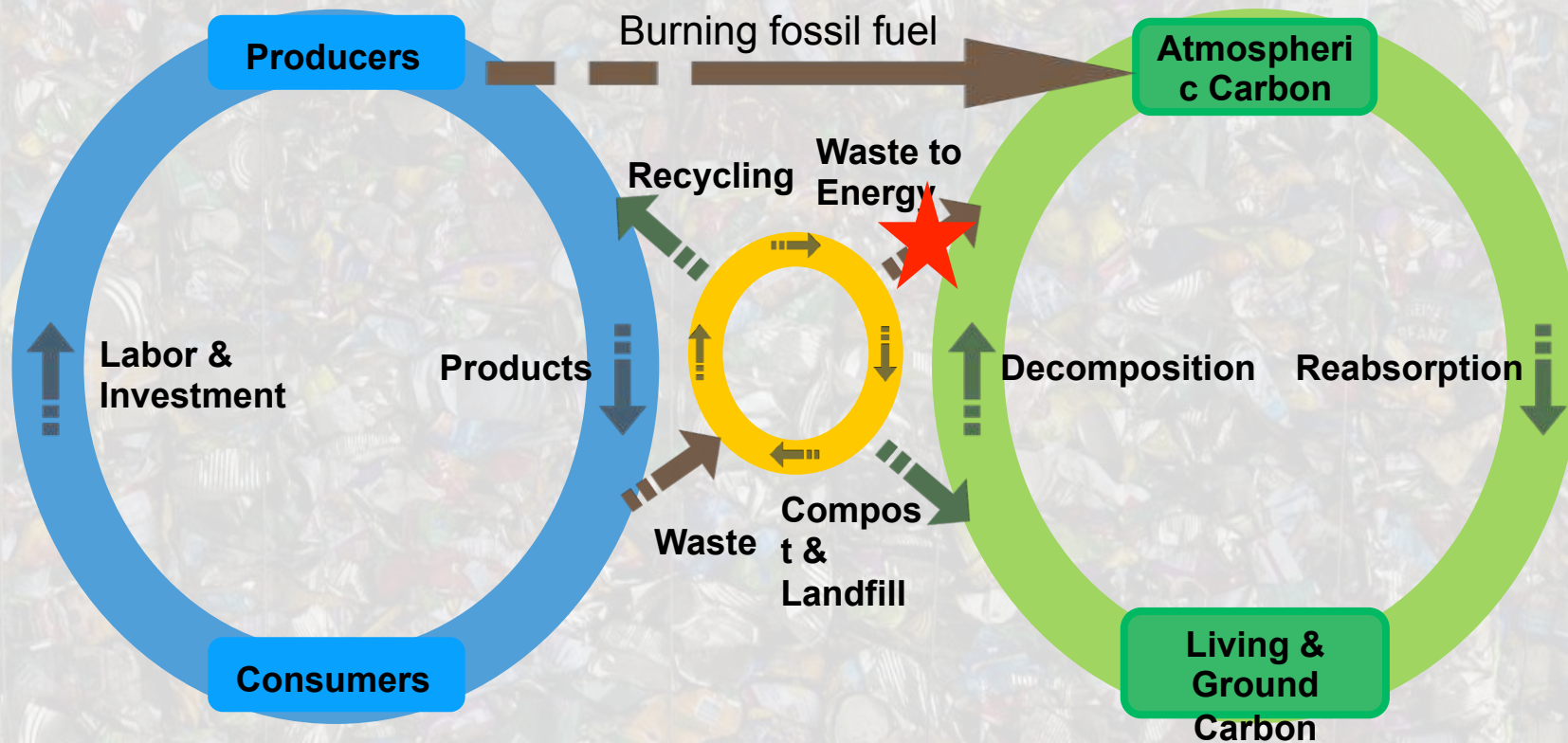


- Deposit-refund started long ago by companies that wanted to reuse bottles; paid a refund for each, and it became a *habit*!
- Do *you* want to count each can or plastic bottle?
- The right subsidy per ton will induce firms to collect bottles.
- Financed by a tax per bottle at the store (easy tax to collect).



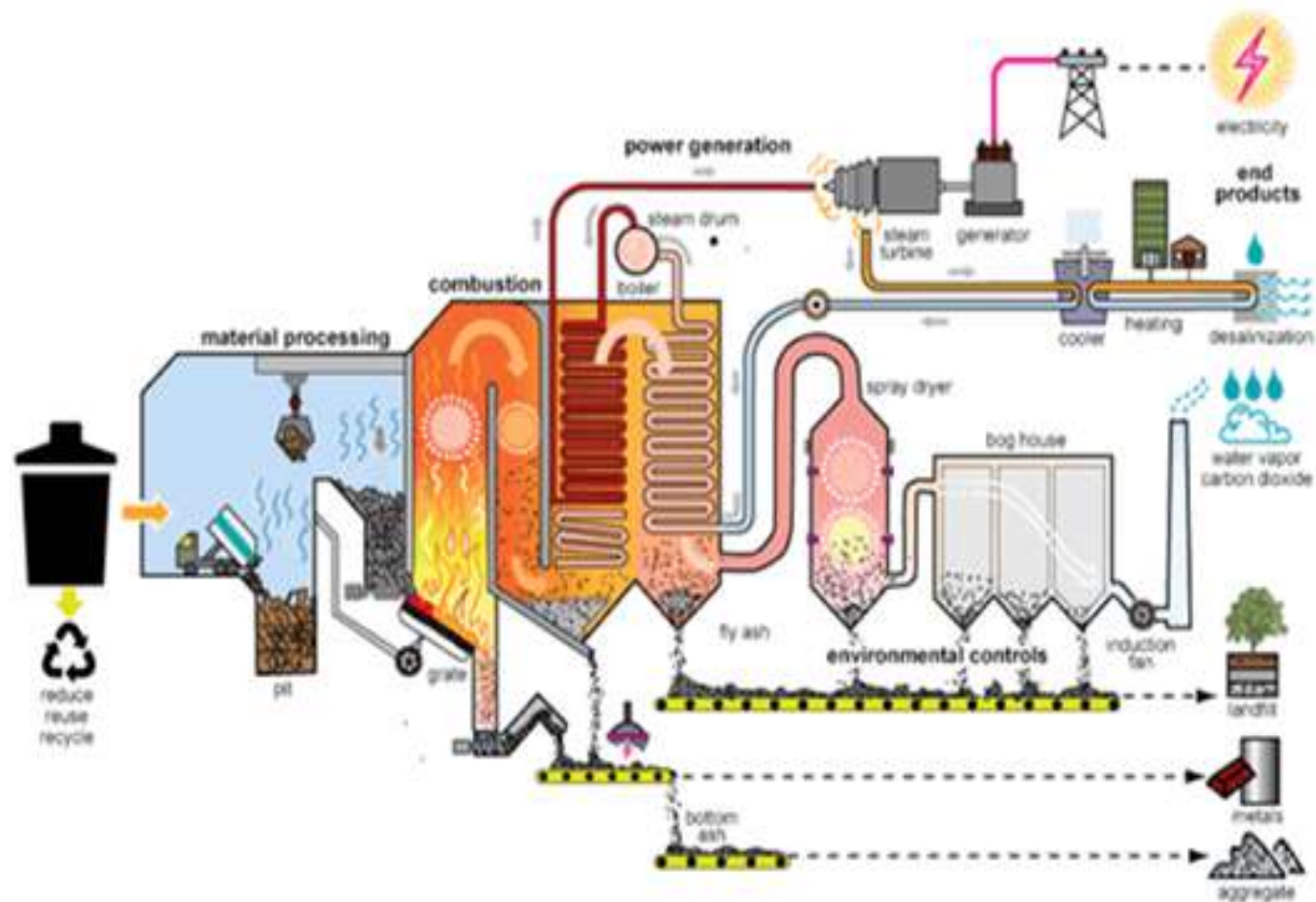
# Tax or subsidy on waste to energy

- Affect production, output, work effort, carbon emissions, and waste of all kinds.



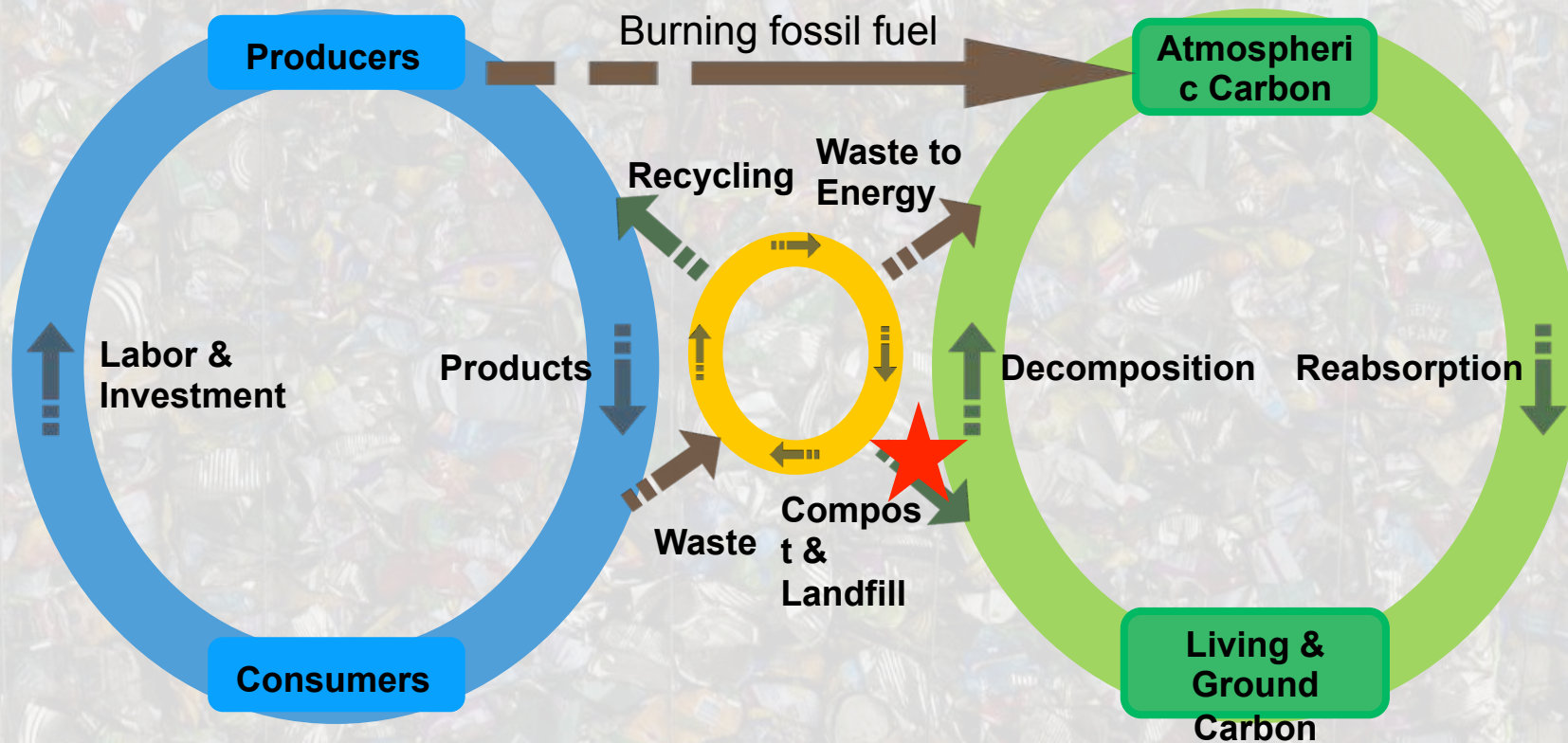


## A mass burn waste-to-energy plant

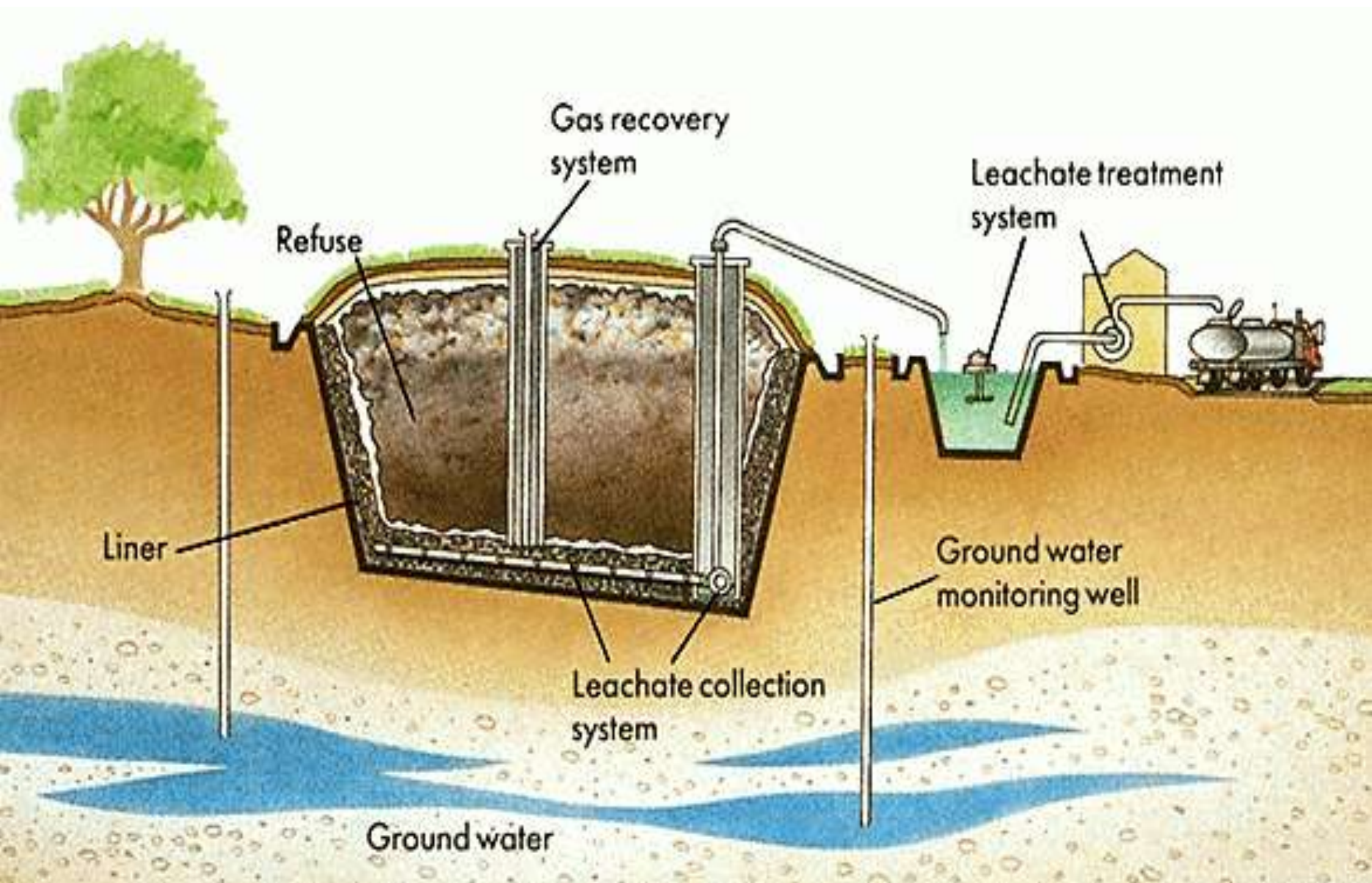




Regulate sanitary landfills;  
prevent illegal dumping and  
burning

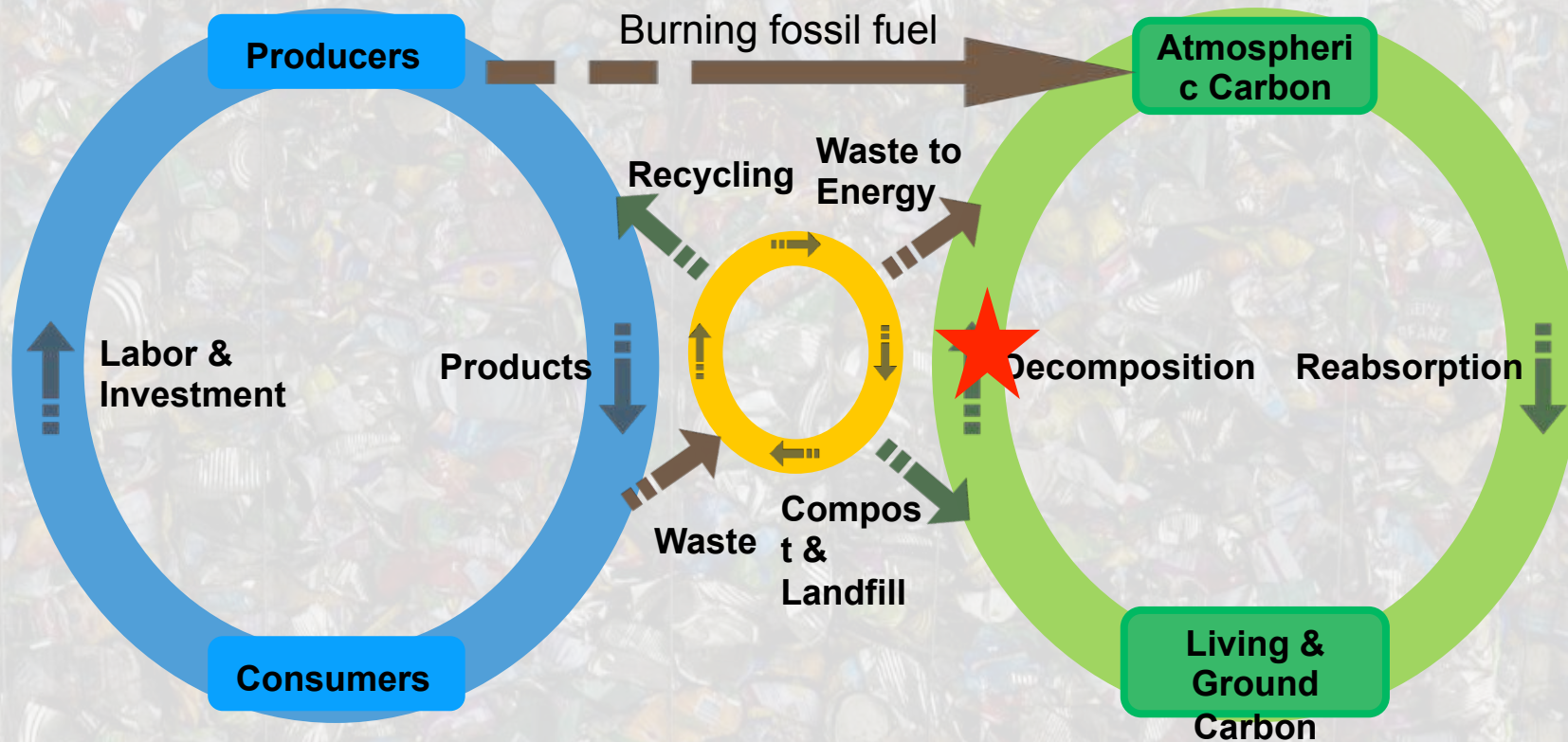








# Policies to Reduce Deforestation, Decomposition, and Release of Carbon





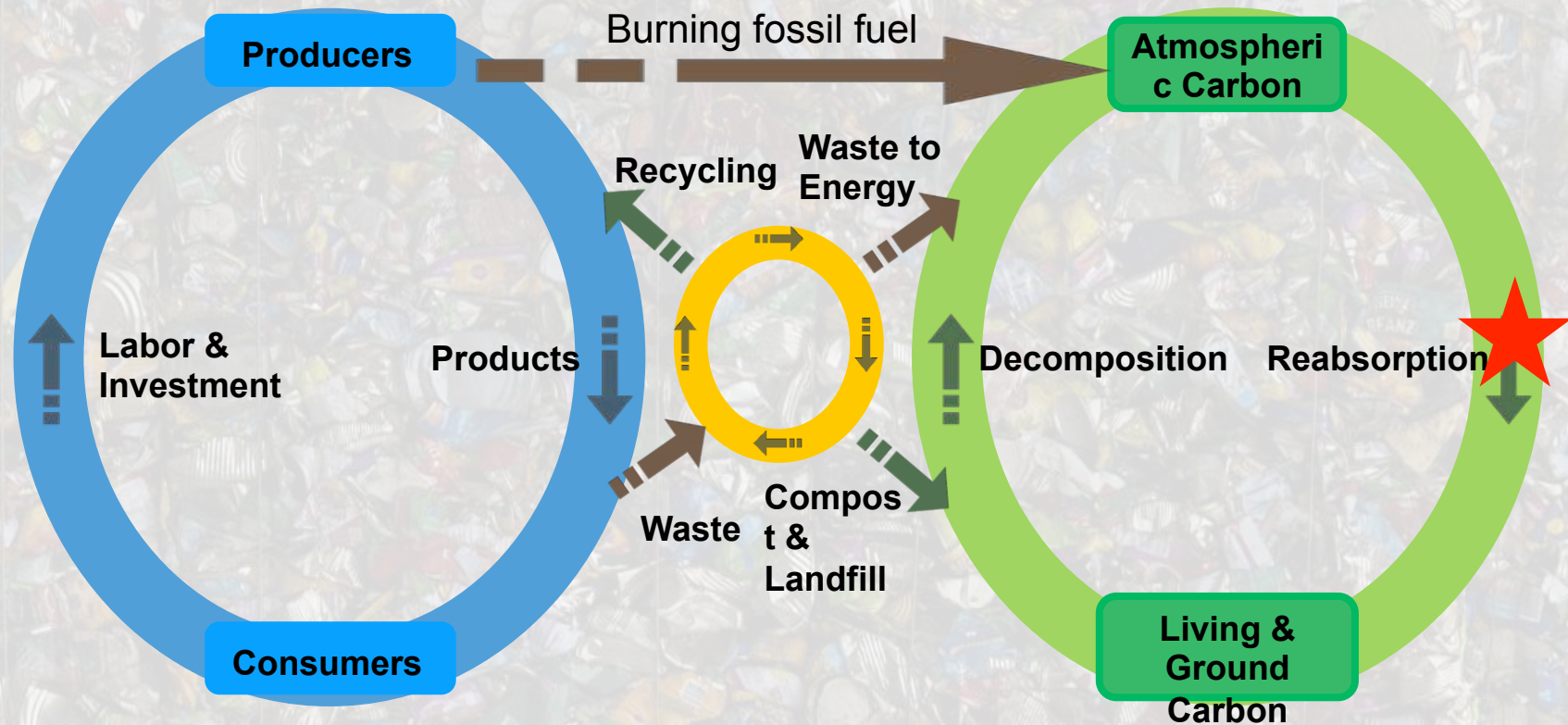
# Reduce deforestation and release of carbon

- Regulate drilling and mining
- No-till farming, to avoid disturbing soil carbon
- Maintain rain forests instead of burning to plant crops.





# Carbon sequestration: add to reabsorption





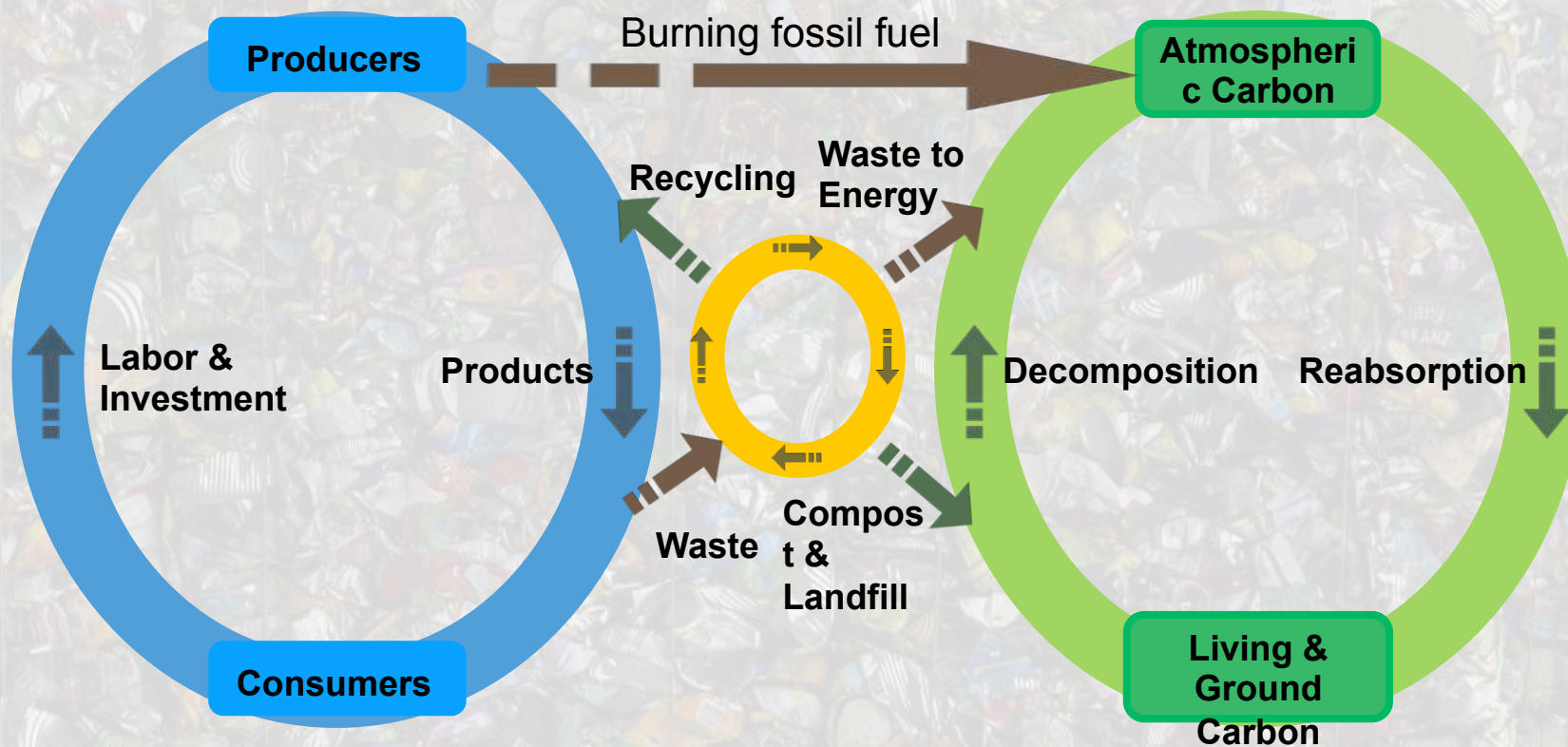
# Carbon sequestration: add to reabsorption

- Plant more trees
- Build houses using lumber
- Carbonate veins form when water containing dissolved carbon dioxide flows through these rocks in Oman (NY Times, May 6, 2018)





With the right mix of policy interventions,  
everything can be kept in **balance**  
... and we can *keep* our balance to ride!





# Thank you very much!

