Landfills & Greenhouse gas emissions

Breathing (biogenic) vs. Fossil fuel combustion (anthropogenic)…

- Average person exhales 2.3#/pp/day CO_2
- 27% of that is carbon = 0.621#
- Everyone exhales = 2.94B tons/year
- Fossil fuel combustion = 34.7B tons/year

INHALED / EXHALED

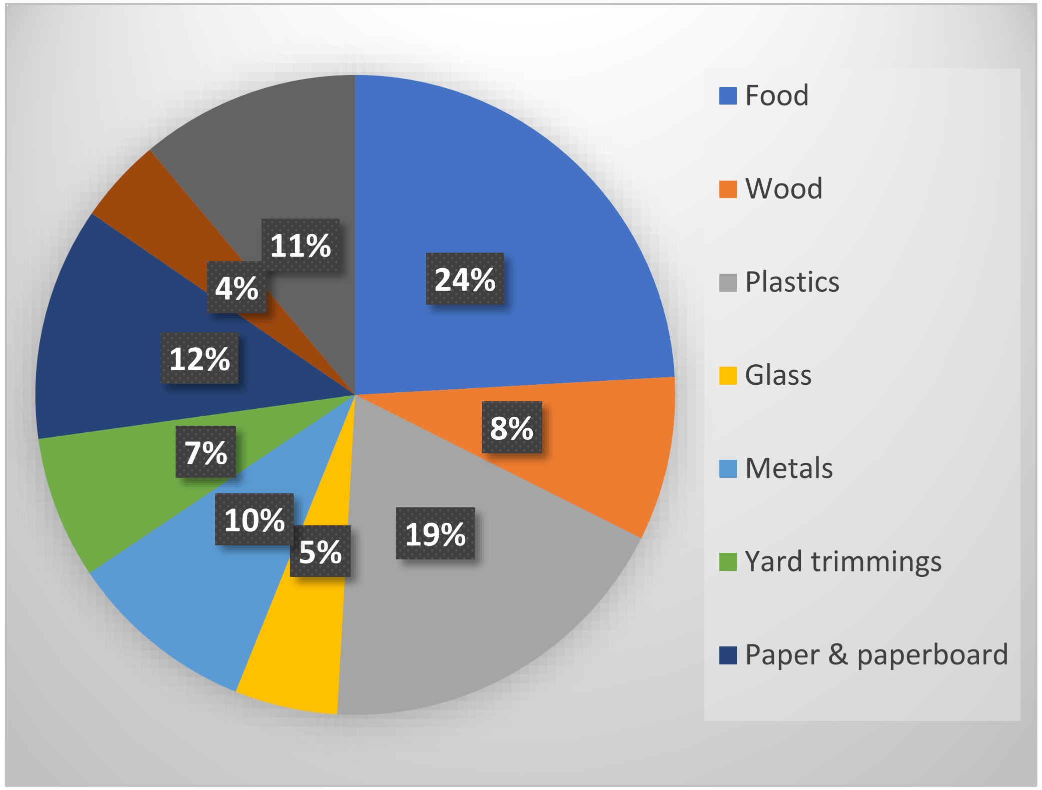
$$C_{55}H_{104}O_6 + 78\,O_2 \longrightarrow 55\,CO_2 + 52\,H_2O$$

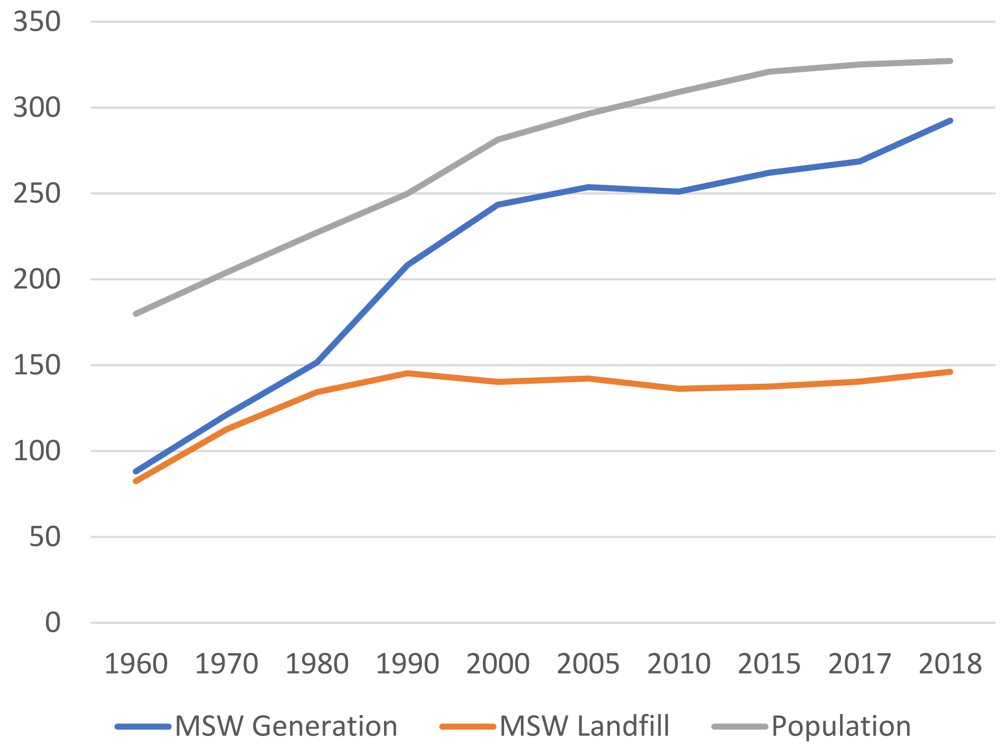
FAT — OXYGEN — CARBON DIOXIDE — WATER

Where do trees get most of their mass?

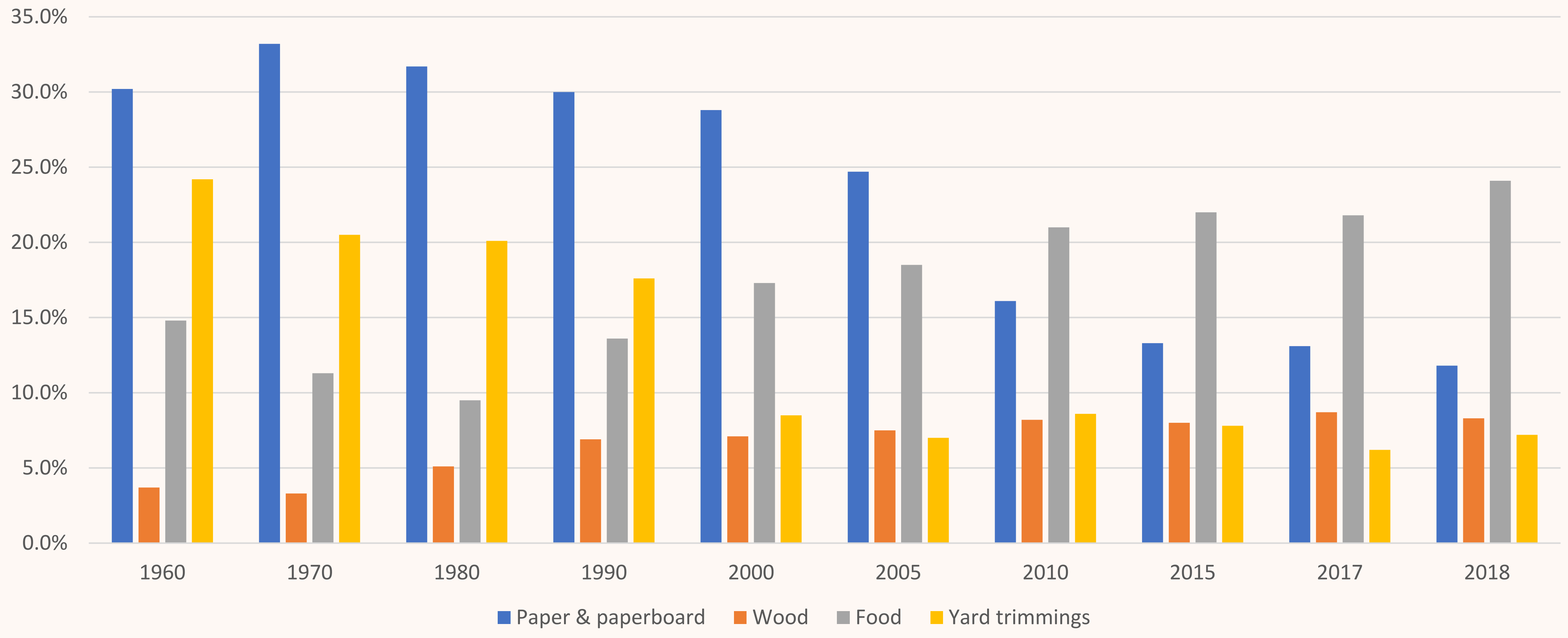
Background

EPA - MSW landfilling (top down)



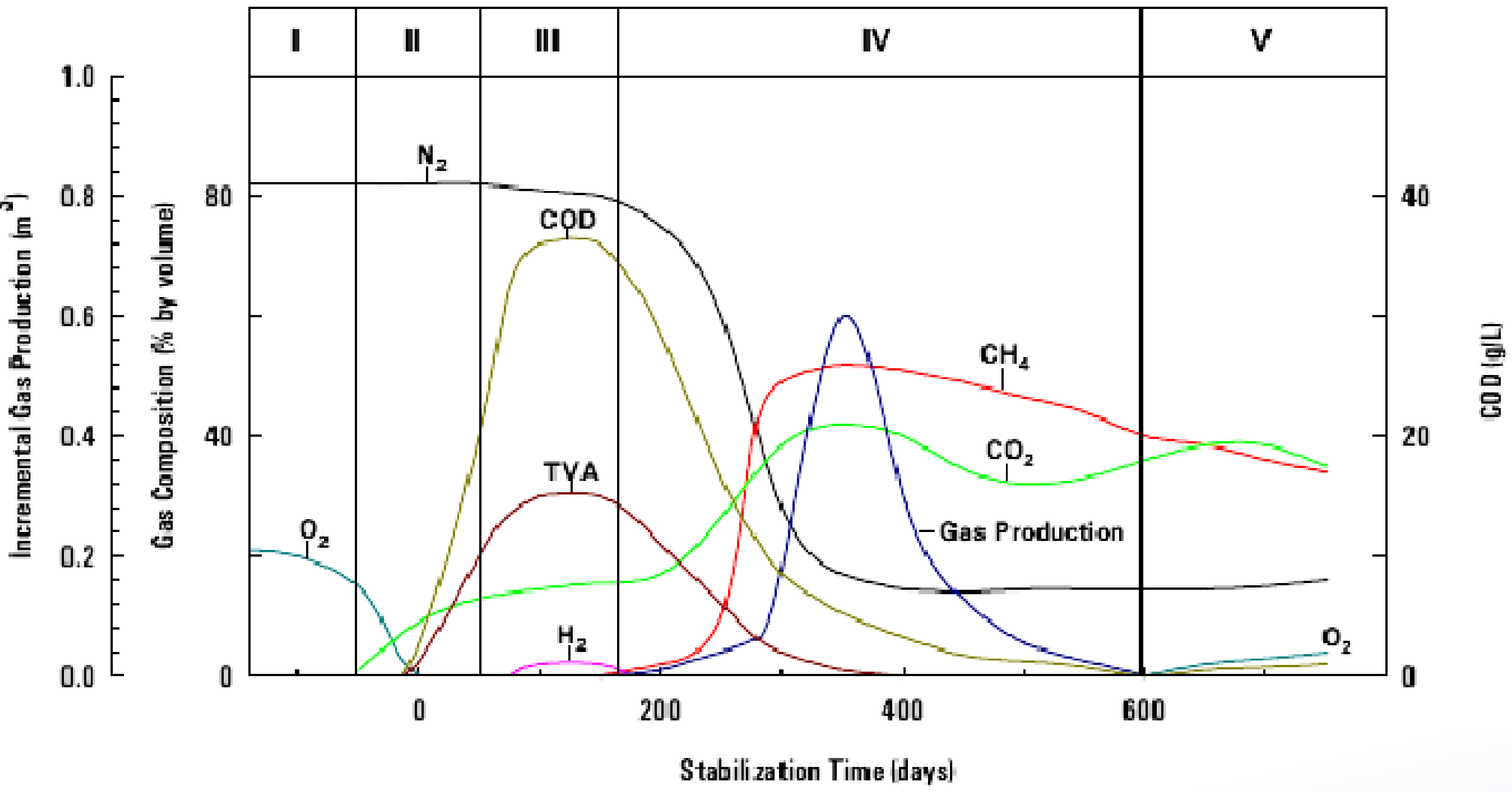


EPA landfilled degradable organics (top down)

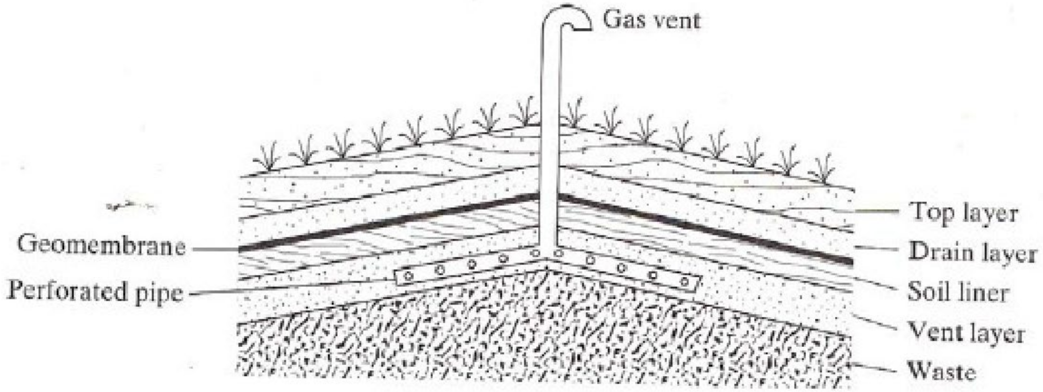


Food waste – State waste characterization studies (bottom up)

- California 2018 – 14.9%, 2014 – 18.1%, 2008 – 16.5%
- Connecticut 2015 – 22.3%
- Delaware 2016 – 21.1%
- Minnesota 2013 – 17.8%
- Missouri 2016/2017 – 15.0%
- Vermont 2017 – 19.3%
- Washington 2015/2016 – 17.0%
- Wisconsin 2020/2021 – 14.1%



Landfill gas production



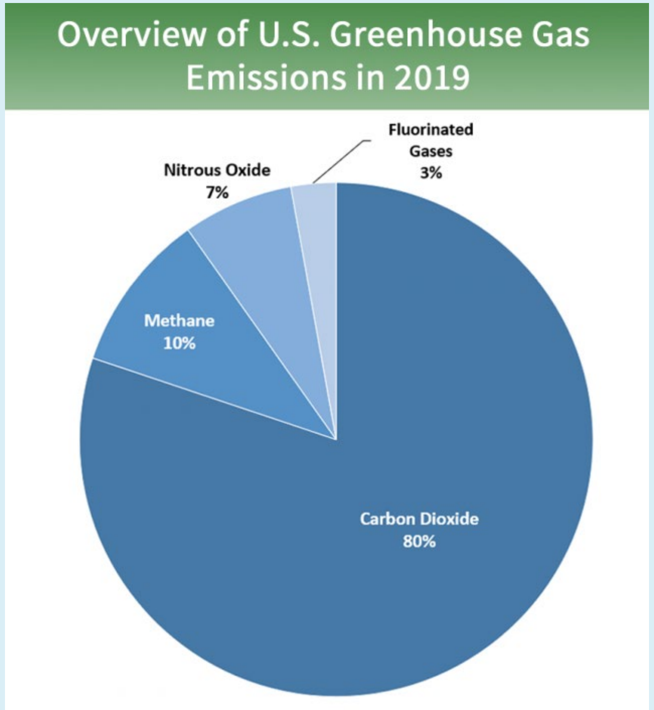
In the beginning…

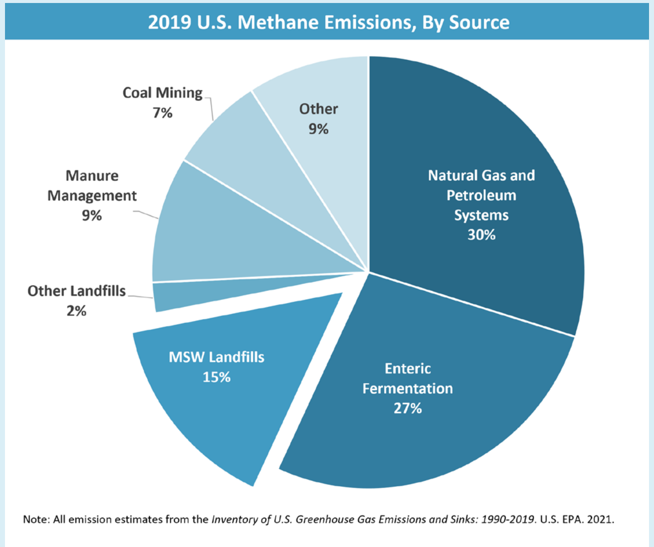
Regulating landfill gas

- EPA New Source Performance Standards Subpart WWW
  - First promulgated in 1996
  - Requires landfill gas collection & control when >50 Mg/year in NMOC generated
  - NMOC = *non-methane* organic compounds!
- EPA NSPS XXX
  - Now required >34Mg/yr
  - Anticipated to reduce 290,000 Mg/yr methane (24 MMT/yr CO2e) (about 25% of current MSW landfill methane emissions)
- SCOTUS 2007 decision in Massachusetts v. EPA established GHGs as air pollutants; upheld in 2012

GHG Inventory

EPA greenhouse gas reporting program & inventory



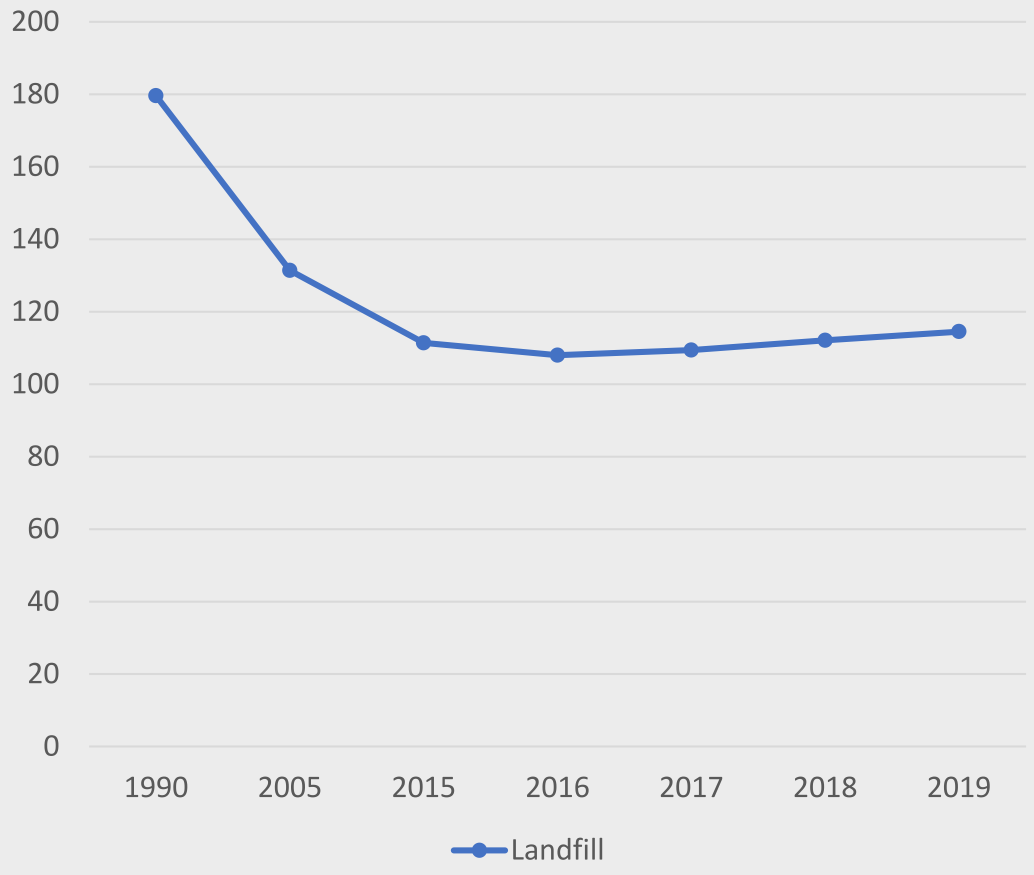


- GHG reporting program
  - Site specific
- GHG inventory
  - Uses reporting program data
  - + Scale up factor to account for non-reporting landfills

Landfill gas emissions

1990-2019

- Population – up 30%
- Landfilling tonnage – flat
- Landfill gas emissions – down 35%



How landfill emissions are determined…

Landfills are area sources…

Direct measurement of fugitive landfill gas emissions is not available

Landfill emissions are estimated ….

Top down:

$$\text{Emissions} = \left[\left(G_{CH\,4} - \textstyle\sum_{n-1}^{N} R_n\right) \times (1 - \text{OX}) + \textstyle\sum_{n-1}^{N} \left\{R_n \times \left(1 - \left(\text{DE}_n \times f_{\text{Dest},n}\right)\right)\right\}\right] \quad \text{(Eq. HH-6)}$$

Bottom up:

$$\text{Emissions} - \left[\left(\frac{1}{\text{CE}}\left\{\textstyle\sum_{n=1}^{N} \left[\frac{R_n}{f_{\text{Rec},n}}\right]\right\} - \textstyle\sum_{n-1}^{N} R_n\right) \times (1 - \text{OX}) + \textstyle\sum_{n=1}^{N} \left\{R_n \times \left(1 - \left(\text{DE}_n \times f_{\text{Dest},n}\right)\right)\right\}\right] \quad \text{(Eq. HH-8)}$$

Generation

Generation is predominantly a function of:

- quantity of waste
- percentage of waste with degradable carbon
- climate (wet or dry)
- decay rate (k-value)

k-value varies. For example:

- low as 0.02 (wood in an arid region)
  - ~34 years for half of the carbon to decay
- high as 0.185 (food or sewage sludge in a wet region)
  - ~4 years for half the carbon to decay

Bottom-up method

- Collection efficiency based on weighted average of areas with:
  - no active collection – 0%
  - daily - 60%
  - intermediate - 75%
  - final cover - 95%
- The more you collect, the more you emit???
- Methodology does not reduce emissions for “good behavior”

For example:

Assume collection efficiency weighted average = 75%

Annual recovery = 65,000 metric tons CO_2e

Emissions ~19,500 metric tons CO_2e

If cover is unchanged but recovery is increased to 70,000 metric tons CO_2e, emissions would increase to ~21,000 metric tons CO_2e

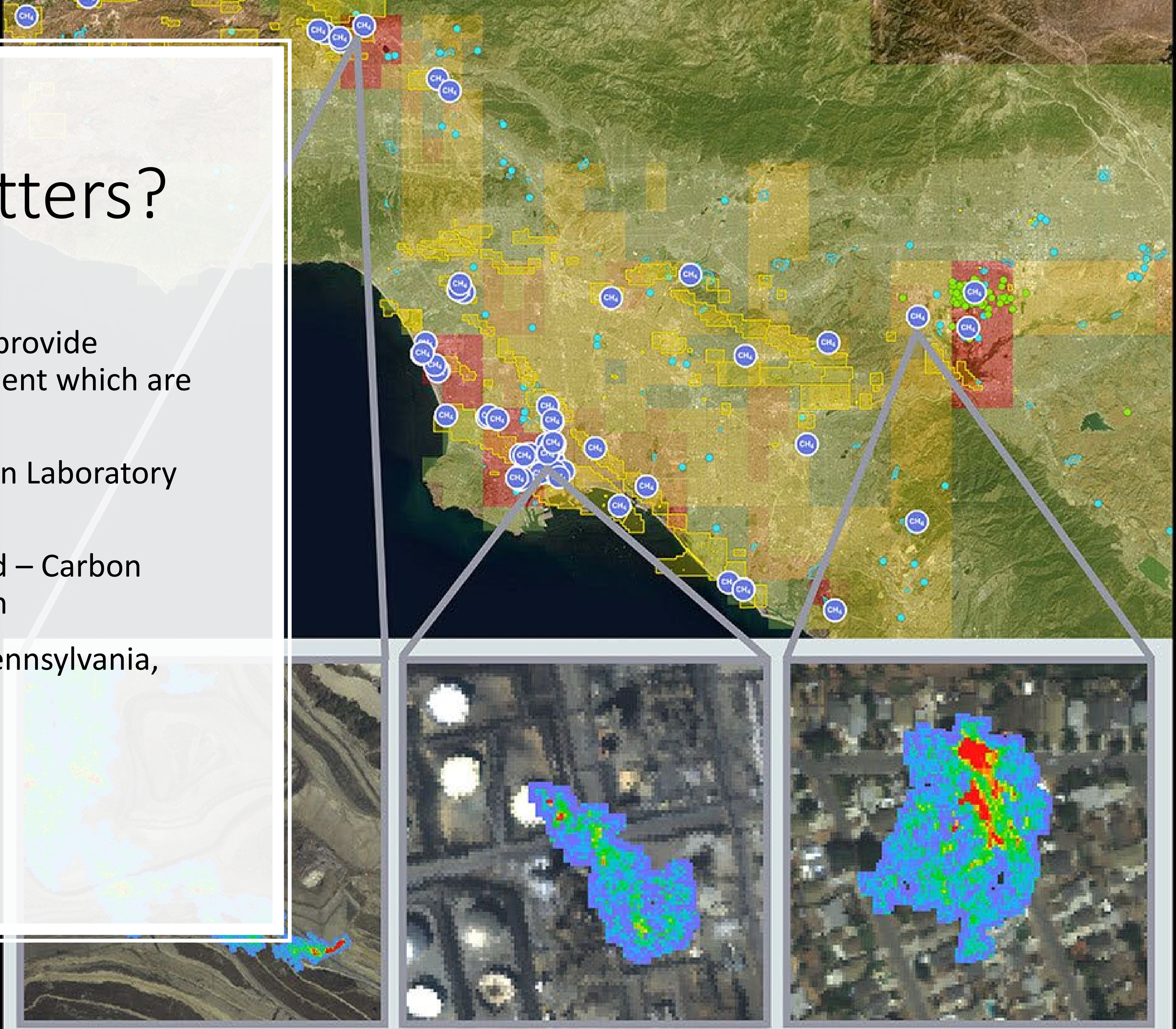
Methane oxidation

- EPA allowable:
  - 0% - geomembrane cover & <12” cover for >50% of area
  - 10% - Default or:
    - <50% areas with interim/final cover
    - methane flux >70 g/m2/day
  - 25% - >50% cover + 10-70 g/m2/d flux
  - 35% - >50% cover + <10 g/m2/d flux
- Field measurements average – 30-40%

Flyovers

Super Emitters?

- Flyovers of landfills provide snapshot measurement which are extrapolated
- NASA's Jet Propulsion Laboratory conducting flyovers
- Satellites anticipated – Carbon Mapper 2023 launch
- States: Maryland, Pennsylvania, California, Others?



California Methane Survey

- Point source plumes observed at 32 out of 436 landfills
  - Construction of new wells
  - Gaps in intermediate cover
  - Leaking gas wells
- Undetected sources “suggest…[that] those facilities emit methane as area sources”

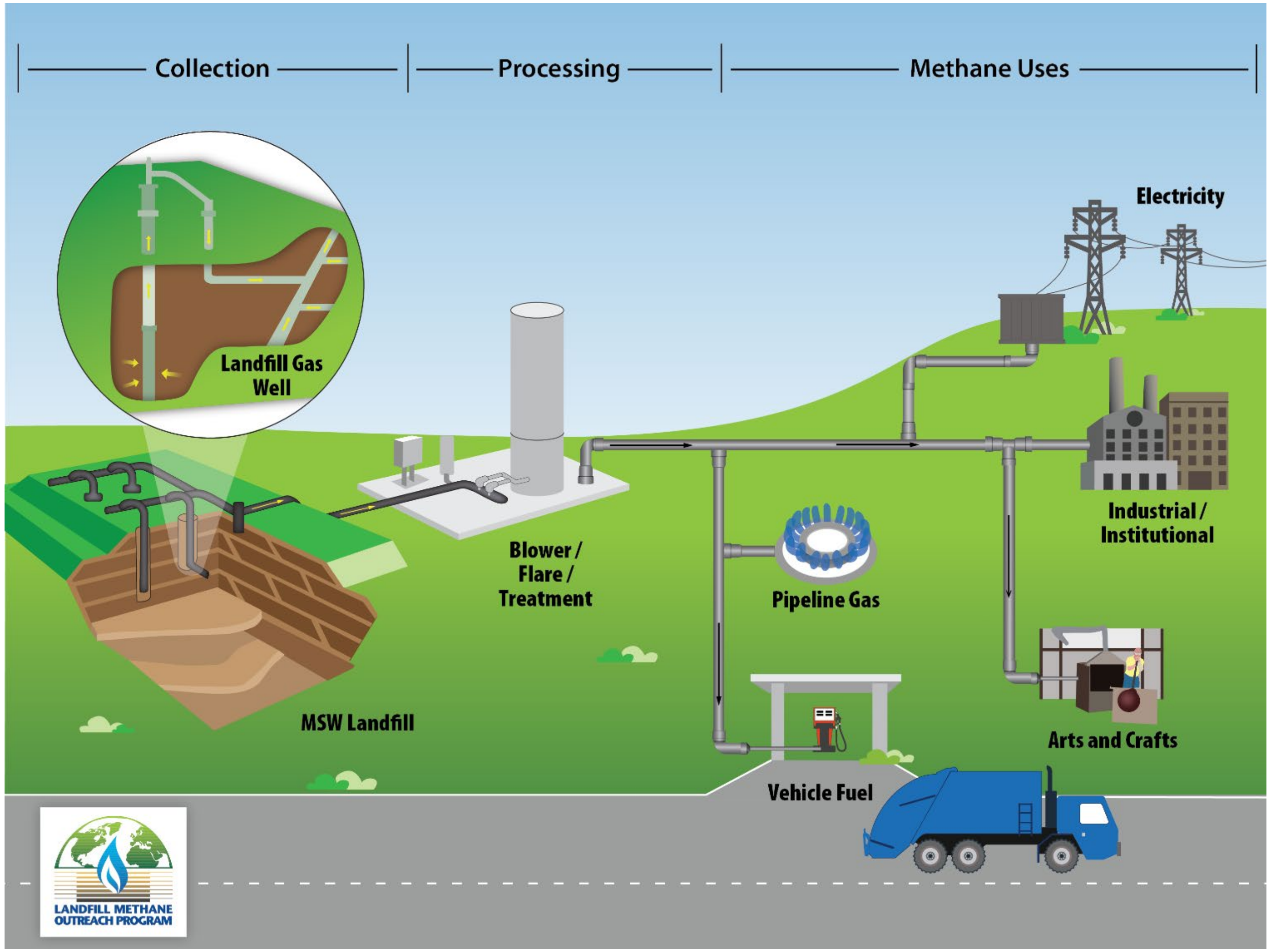
Landfill gas utilization

Landfill gas utilization benefits

- Reduce air pollution through avoided use of non-renewable (not limited to GHGs, but also SOx, NOx, & HAPs)
- GHG benefits for typical 3 MW project (EPA):
  - Carbon sequestered > 196k acres of forests in one year
  - CO2 > 830 railcars worth of coal burned
  - CO2 > 17 M gallons of gasoline
  - Energy benefit = powering 1900 homes

LFG utilization

- 548 operational projects
- 483 candidate landfills



Sequestration

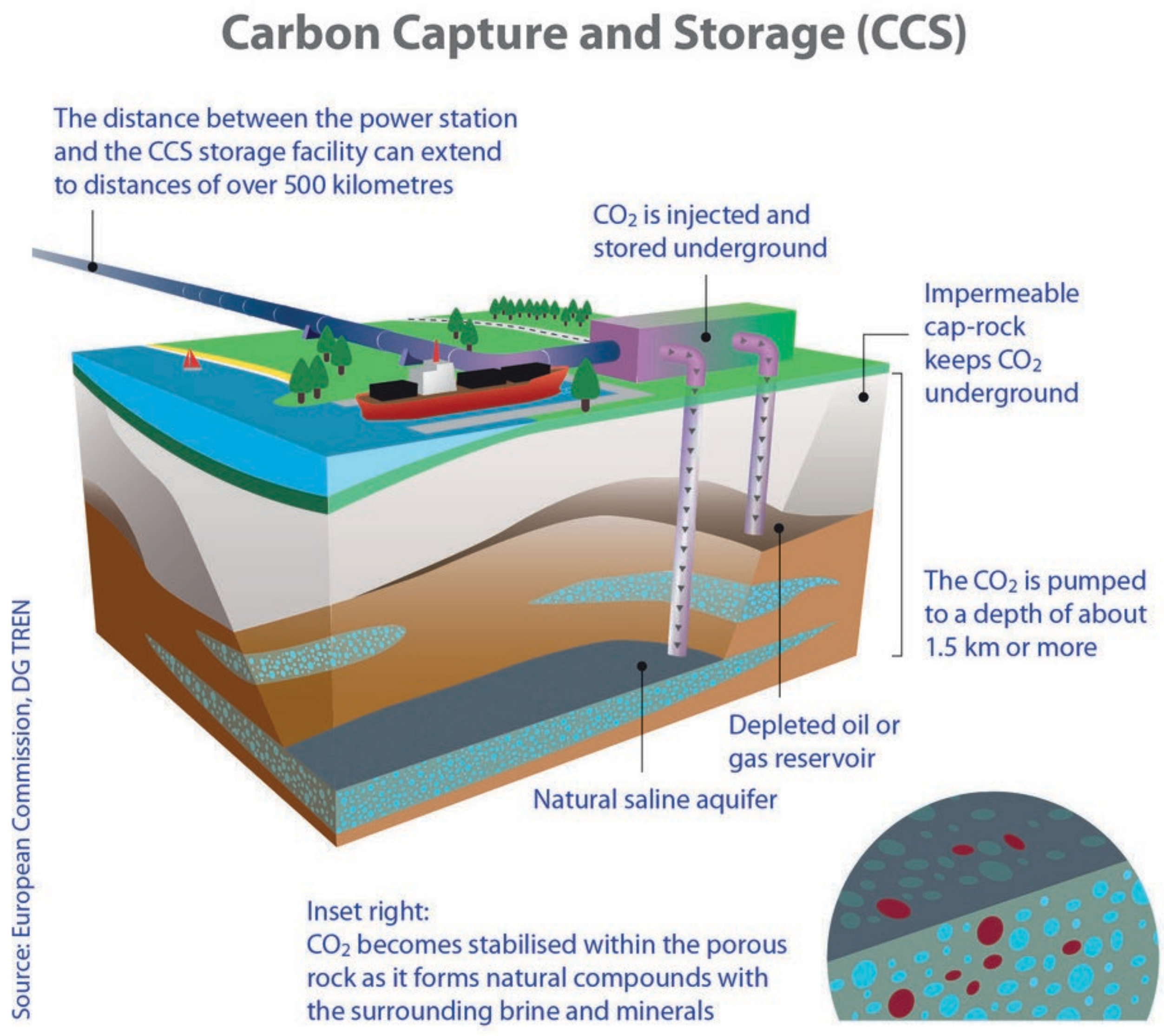
GHG Inventory – Carbon Sequestration (CO_2e)

Table 6-8: Net CO_2 Flux from Forest Ecosystem Pools in *Forest Land Remaining Forest Land* and Harvested Wood Pools (MMT CO_2 Eq.)

Carbon Pool	1990		2005		2015	2016	2017	2018	2019
Forest Ecosystem	**(663.8)**		**(555.5)**		**(582.7)**	**(629.5)**	**(564.0)**	**(599.8)**	**(583.3)**
Aboveground Biomass	(456.4)		(401.3)		(414.2)	(421.3)	(395.1)	(402.4)	(394.0)
Belowground Biomass	(103.7)		(92.0)		(92.6)	(95.0)	(89.2)	(90.9)	(89.2)
Dead Wood	(97.3)		(93.5)		(98.7)	(105.1)	(97.1)	(101.7)	(99.3)
Litter	(8.1)		32.2		30.5	(3.2)	0.2	(2.3)	(0.5)
Soil (Mineral)	1.5		(1.5)		(7.3)	(6.8)	14.3	(4.5)	(2.4)
Soil (Organic)	(0.6)		(0.2)		(1.1)	1.2	2.1	1.2	1.2
Drained Organic Soil[a]	0.8		0.8		0.8	0.8	0.8	0.8	0.8
Harvested Wood	**(123.8)**		**(106.0)**		**(88.7)**	**(92.4)**	**(95.7)**	**(98.8)**	**(108.5)**
Products in Use	(54.8)		(42.6)		(24.6)	(27.8)	(30.3)	(31.5)	(39.2)
SWDS	(69.0)		(63.4)		(64.1)	(64.6)	(65.5)	(67.2)	(69.3)
Total Net Flux	**(787.6)**		**(661.5)**		**(671.4)**	**(721.9)**	**(659.7)**	**(698.6)**	**(691.8)**

Notes: Forest ecosystem C stock changes do not include forest stocks in U.S. Territories because managed forest land for U.S. Territories is not currently included in Section 6 Representation of the U.S. Land Base. The forest ecosystem C stock changes do not include Hawaii because there is not sufficient NFI data to support inclusion at this time. However, managed forest land area for Hawaii is included in Section 6 Representation of the U.S. Land Base so there are small differences in the forest land area estimates in this Section and Section 6. See Annex 3.13, Table A-214 for annual differences between the forest area

Collect CO_2 from LFGTE



Do all organics degrade?

What keeps organics from breaking down?

- Preservatives - salt
- Temperature - cold
- Moisture - arid
- pH – peat bogs

is the proof! This @centredaily was dug up from the Clinton County Landfill. Date: 8/6/91. Still readable after buried in a landfill for 27 years. #recycle

3:32 PM · Aug 9, 2018 · Twitter Web Client

Why We Dug Atari

"Punk archaeologists" explain that they went looking for more than just video-game cartridges in a New Mexico landfill.

By William Caraher, Raiford Guins, Andrew Reinhard, Richard Rothaus, and Bret Weber

Atari's dumped games unearthed (Raiford Guins)

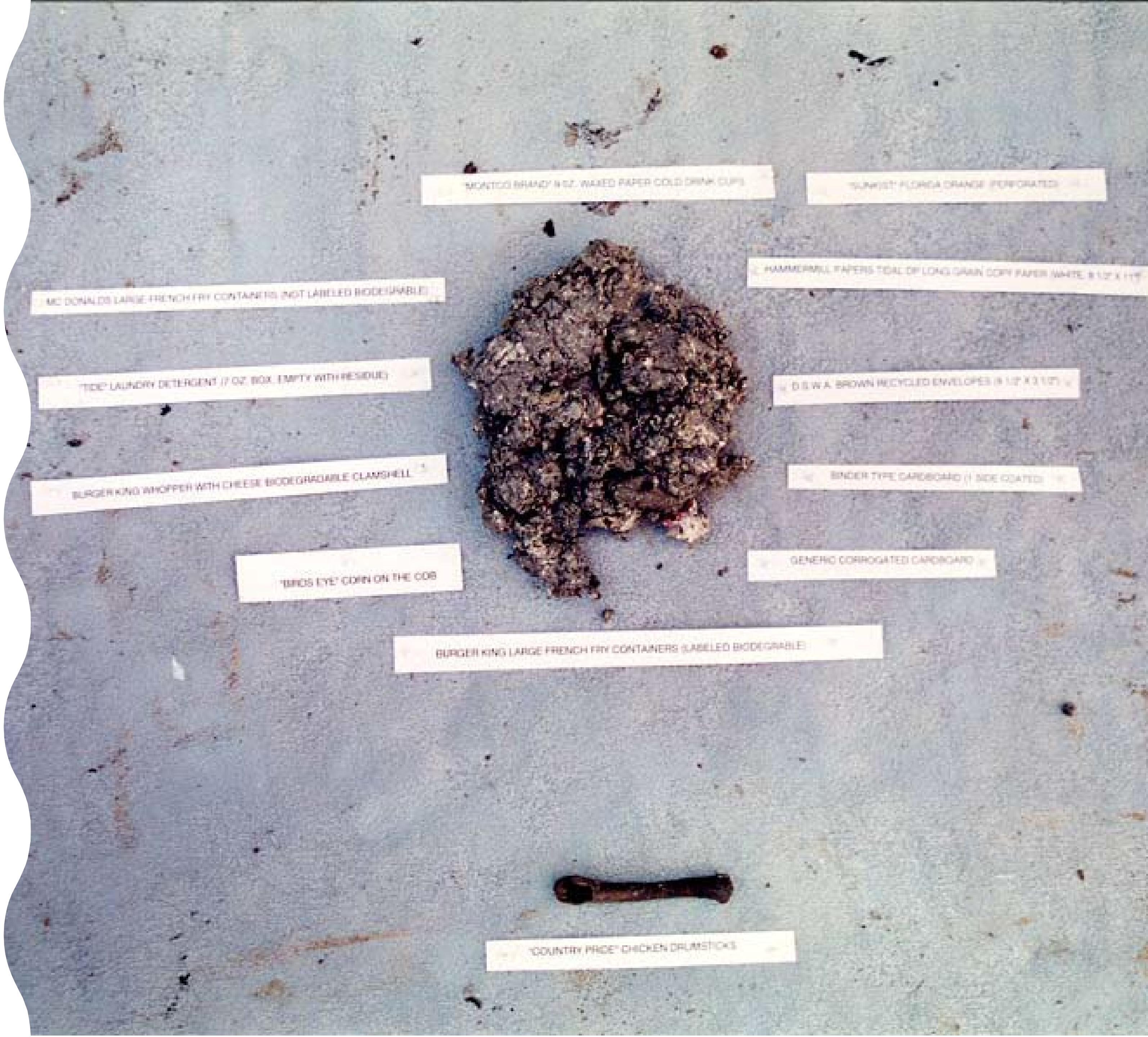
Degradable carbon?

DSWA test cells

- Two 1-acre landfill cells
- Time capsules with identical materials placed in 1990
- Extracted in 1998

Test Cell #1 – Wet

- Waste buried – 1990
- Capsule removed – 1998
- Burial time – 8 years



Test Cell #2 – Dry

- Waste buried – 1990
- Capsule removed - 1998
- Burial time – 8 years


Chicken Leg

Conclusion

Moving towards net zero

- Reduce organics
- Continue to improve LFG collection
  - Focus on point sources: construction activities, cover & leaks
- Continue to improve emissions calculations
  - Methane oxidation estimates
  - k-values
- Increase LFG utilization
- Sequester carbon & carbon dioxide