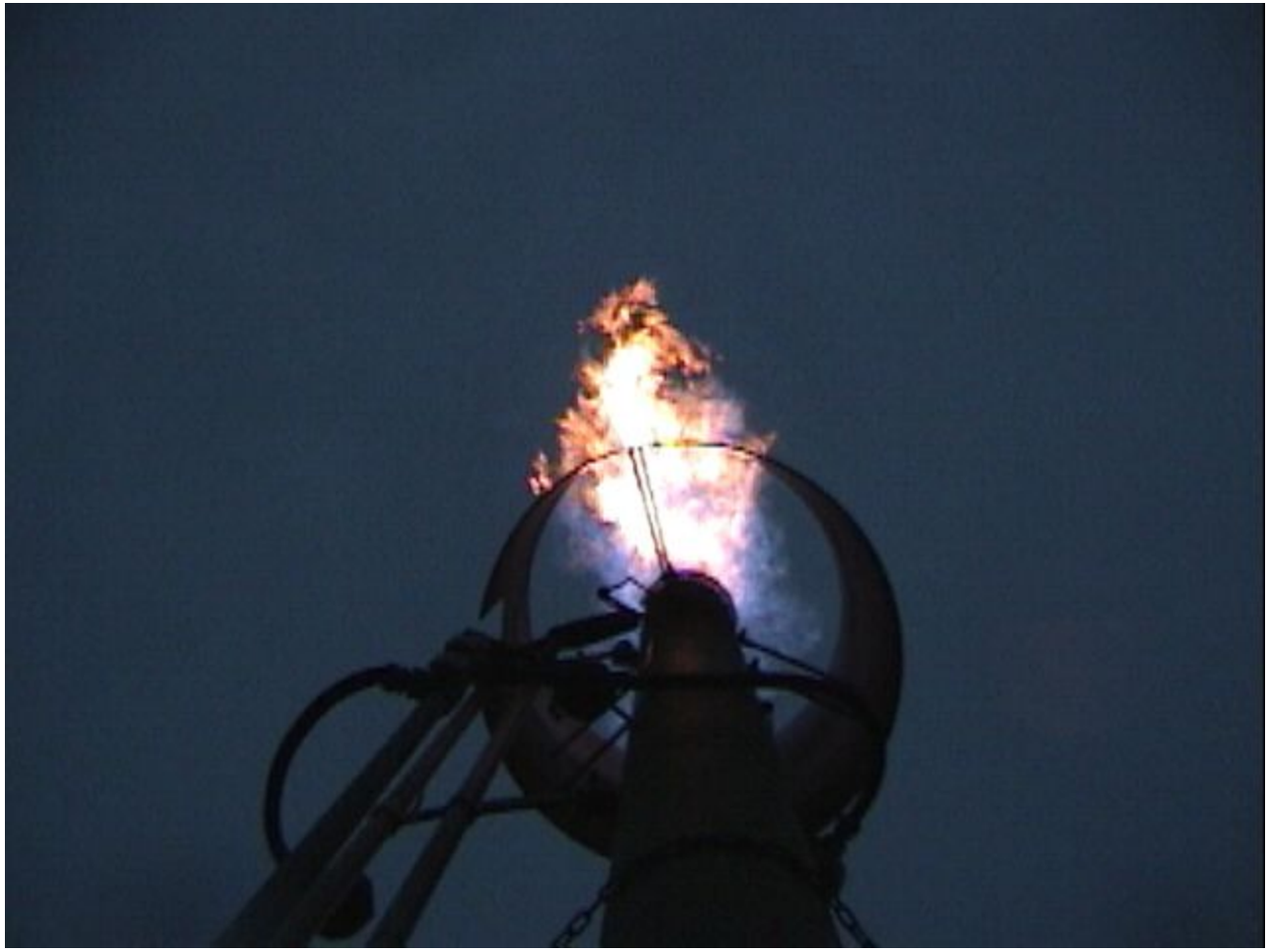
Energy Justice Network

...helping communities protect themselves from polluting energy and waste technologies

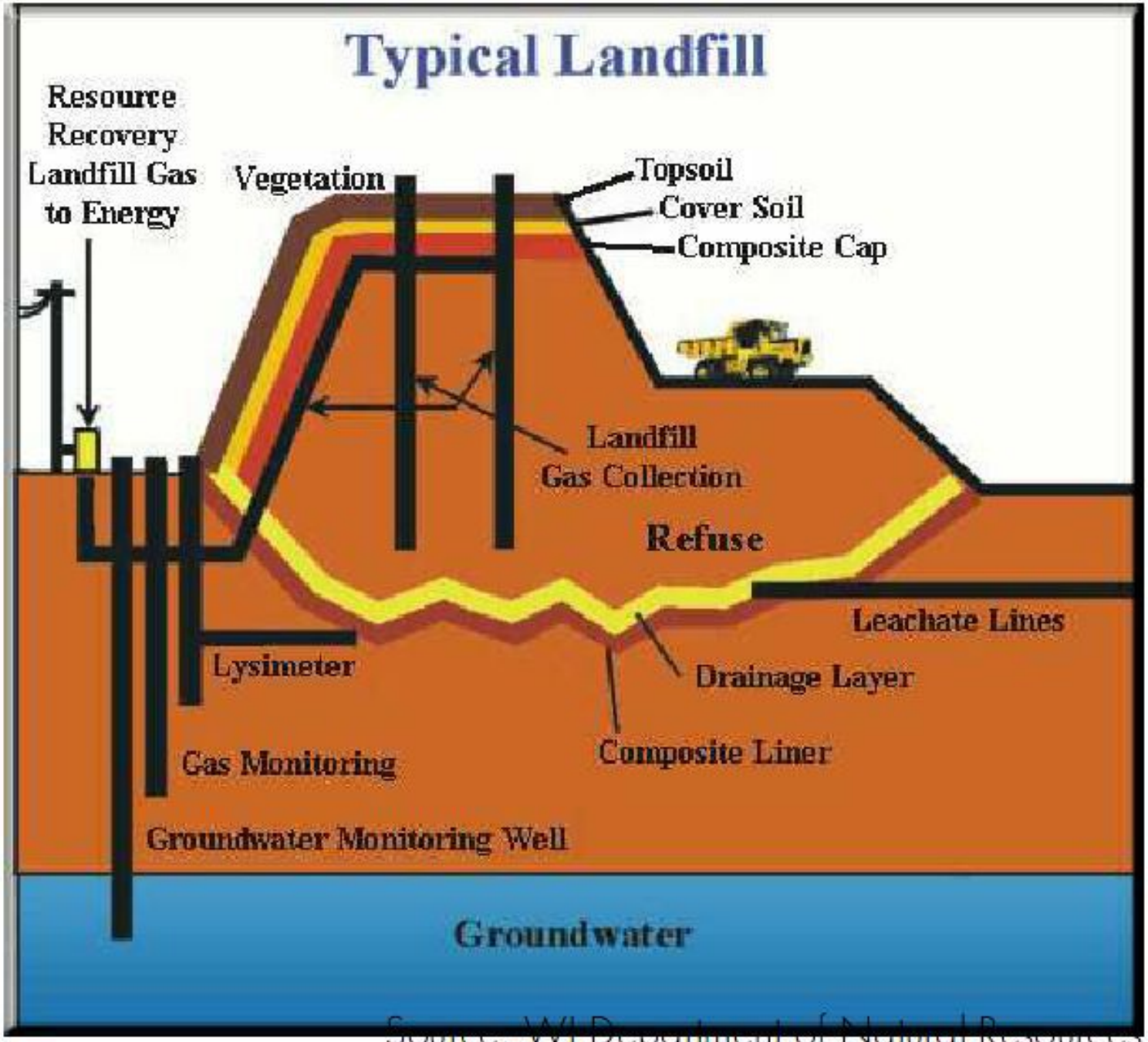
ENERGYJUSTICE.net

Sept 2013

Landfill Gas



www.energyjustice.net/lfg/



Source: WI Department of Natural Resources

All Landfills Leak

- U.S. EPA acknowledges that all landfill liners leak within 20 years, if not sooner
- Landfill liners are only guaranteed for about 20 years
- Landfills are permitted to leak a certain amount of gallons/acre
- It's easy not to find leakage (underground or in air); testing is often inadequate

Landfill Gas: What it is…

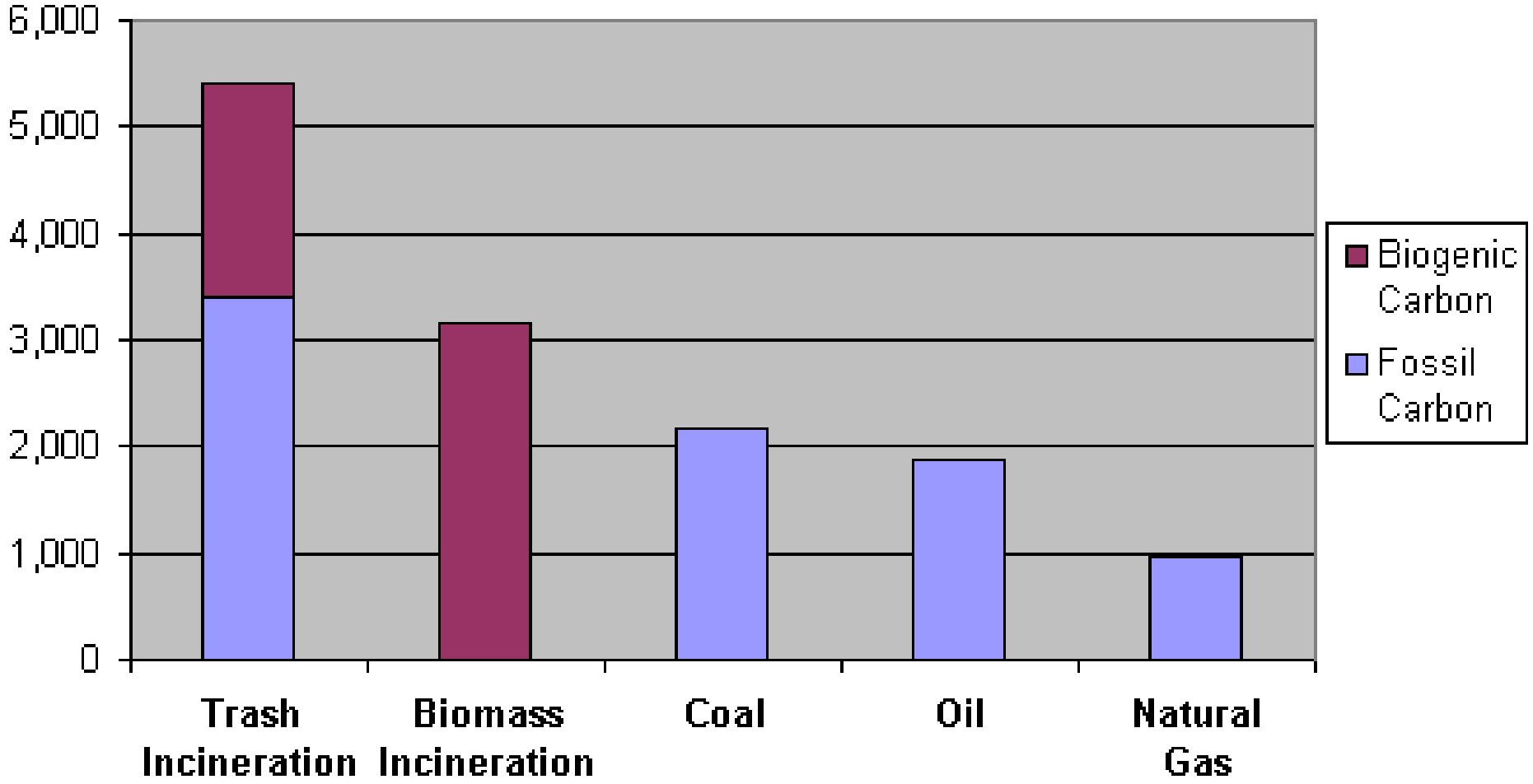
- Not simply “methane”
- About half methane, half CO_2
- Organics breaking down create the methane; methane helps the toxic chemicals escape
- Hundreds of toxic contaminants
  - Halogenated compounds (trichloroethane, vinyl chloride, carbon tetrachloride and many more)
  - Mercury (methylmercury – the really bad kind)
  - Sulfur compounds (the stinky stuff)
  - Tritium (radioactive)
  - Other toxic organic compounds (benzene , toluene…)

1 -butanol	2,6-dimethylheptane	4-methyl-2-pentanol + branched C-8 paraffin	butanol isomer?
1 -chloro-1 -fluoroethane	2-butanethiol	acetaldehyde	butyl hexanoate
1 -chloro-1 -propene	2-butanol	acetone	butylcyclohexane
1 -chloropropane	2-chloropropane	acetone + ethanol	butylene
1 -heptene	2-ethylfuran	alpha thujene	butylpropanoate
1 -octene	2-ethylhexyl alcohol	alpha-pinene	C-1 0 olefin
1 -pentene	2-ethyl-l-hexanol	alpha-thugene	C-1 1 diene
1 -propanol	2-methyidecalin	alpha-thujene	C-1 1 olefin
1, 1 -dichloroethane	2-methyl heptane	alpha-thujene + branched C-10 paraffin	C-1 1 paraffin
1, 1, 1 -trichloroethylene	2-methyl propanoate	benzene	C-1 1 paraffin + C-3 benzene
1, 1,2,3-tetramethyl-cyclohexane	2-methyl-2-propanethiol	benzothiazole	C-1 I cylcoparaffin
1,1,3-trimethylcyclohexane	2-methyl-3-pentanone + pentanol isomer	beta-pinene	C-10 diene
1,1-dichloroethane	2-methylbutane	branched C-1 1 olefin	C-10 olefin
1,1-dimethyl-cyclopropane	2-methyl-butane	branched C-1 1 olefin & paraffin + C-1 2 diene	C-12 diene
1,2,3-trimethylcyclohexane	2-methyl-ethyl butanoate	branched C-1 1 olefin + branched C-1 2 olefin	C-3 alkylcyclohexane isomer
1,2,3-trimethylcyclohexane isomer	2-methylfuran	branched C-1 1 paraffin	C-3 alkyl-substituted cyclopentadiene isomer
1,2-dichloroethene	2-methylheptane	branched C-1 I paraffin	C-3 benzene
1,2-dichloroethylene	2-methylhexane	branched C-10 olefin	C-3 benzene + branched C-1 1 paraffin
1,2-dichloropropane	2-methylhexylbutyrate	branched C-10 olefin + branched C-1 1 paraffin	C-3 benzene + branched C-10 olefin + paraffin
1,3,5-trimethylcyclohexane	2-methyl-l-propanol	branched C-10 olefin + C3-benzene, …	C-3 benzene + branched C-10 paraffin
1,3,5-trimethylcyclohexane isomer	2-methyloctahydropentalene	branched C-10 paraffin	C-3 benzene + C-1 1 paraffin
1,3-dichloro-2-butene	2-methylpentane	branched C-10 paraffin + 2-methylhexylbutanoate	C-3 benzene + C-10 paraffin
1,5-cyclooctadiene	2-methylthiobutane	branched C-10 paraffin + beta-pinene	C-3 benzene + C-9 diene
1-butanol	2-methylthiopropane	branched C-10 paraffin + branched C-10 olefin	C-3 benzene + octahydro-2-methylpentalene
1-butanol + 1,2-dichloropropane	2-pentanone + 1,2-dichloropropane	branched C-10 paraffin + phellandrene	C-3 benzene isomer
1-chloropropane	2-pentene	branched C-12 diene	C-3 cyclohexane

Global Warming Pollution

Smokestack CO2 Emissions from U.S. Power Plants

in pounds of CO2 per unit of energy produced (lbs/MWh)



Source: U.S. EPA eGRID 2012 Database

Landfills Worse for Climate than Incinerators

- Study: if landfill gas capture rates are in the 50% to 70% range, their GHG impact is about the same as incinerators.
- Capture rates are lower, making incinerators worse
- Study used old global warming potential for methane, further underestimating GHG landfill impacts

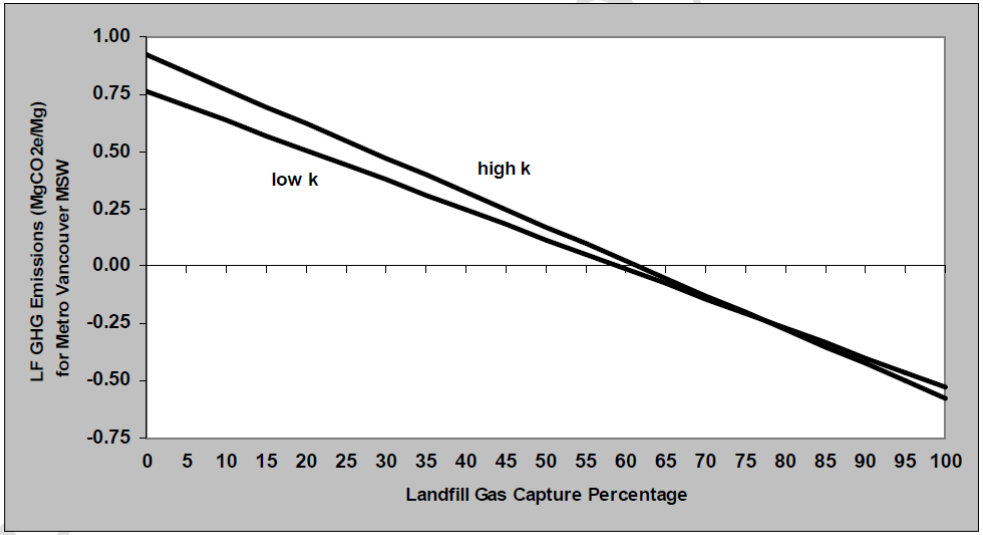


Figure 2: Metro Vancouver MSW Net LF GHG Emissions as a Function of LFG Capture Efficiency

Source: Jeffrey Morris, "Bury or Burn North America MSW? LCAs Provide Answers for Climate Impacts & Carbon Neutral Power Potential," Sound Resource Management Group (2010).

Landfill Gas: Capturing it

- Gas capture requirements based on toxics ("non-methane organic compounds" or NMOCs), not greenhouse gas emissions
- Landfills that estimate releasing over 55 tons/year of NMOCs must collect gas and reuse or "destroy" 98% of them

Landfill Gas: Options

- Flare
- Internal Combustion Engine (electricity)
- Turbine (electricity)
- Boiler (heat/steam)
- Piping into natural gas lines
- Hydrogen production
- Reuse of chemicals (methane and CO_2) for industrial feedstocks

Landfill Gas-to-Energy Emissions

- For some chemicals, burning for electricity is *more* polluting than flaring
  - Carbon monoxide — 2.7 times worse
  - Nitrogen oxides (NOx) — 2.6 times worse
  - Sulfur dioxide (SO_2) — 3% worse
  - Methane — 3% worse
  - Dioxins — 41% worse
  - Methylmercury — worse

    (depends on differences in capture rate)
- Burning halogenated compounds creates significant amounts of dioxins/furans

Landfill Gas – Proper Management

1) **<u>Ban organic wastes from landfills</u>** Clean compost from food scraps and yard waste (not sewage sludge!) can be used in gardening or landscaping. The organic fraction of unsorted trash (after recyclables are removed) should be digested, then monofilled (placed in separate landfill cells), as it'll be too contaminated.

- There is no methane in your trash can.
- Europe and Latin America know to keep organics out of landfills. World Bank and International Panel on Climate Change agree. U.S. EPA ignored this advice.
- Some communities are canceling composting programs to get more organics into their landfills

Composting Collection at a Brazilian Mall Food Court

Landfill Gas – Proper Management

2) ***Minimize* gas production. *Maximize* gas collection.** Do not manage the waste facility as an energy facility by stimulating gas production and increase methane concentration, as more will be released uncaptured (capture rates are not 100%).

- Filter the toxins in the gas into a solid medium like a carbon filter. The carbon filters ought to be containerized and stored on-site.
  - Landfills usually filter only sulfur, water vapor and siloxanes
- They should not go to a carbon "regeneration" or "recycling" facility, since they simply incinerate the chemicals – letting them back out into the environment by burning them out of the filters.

Landfill Gas – Proper Management

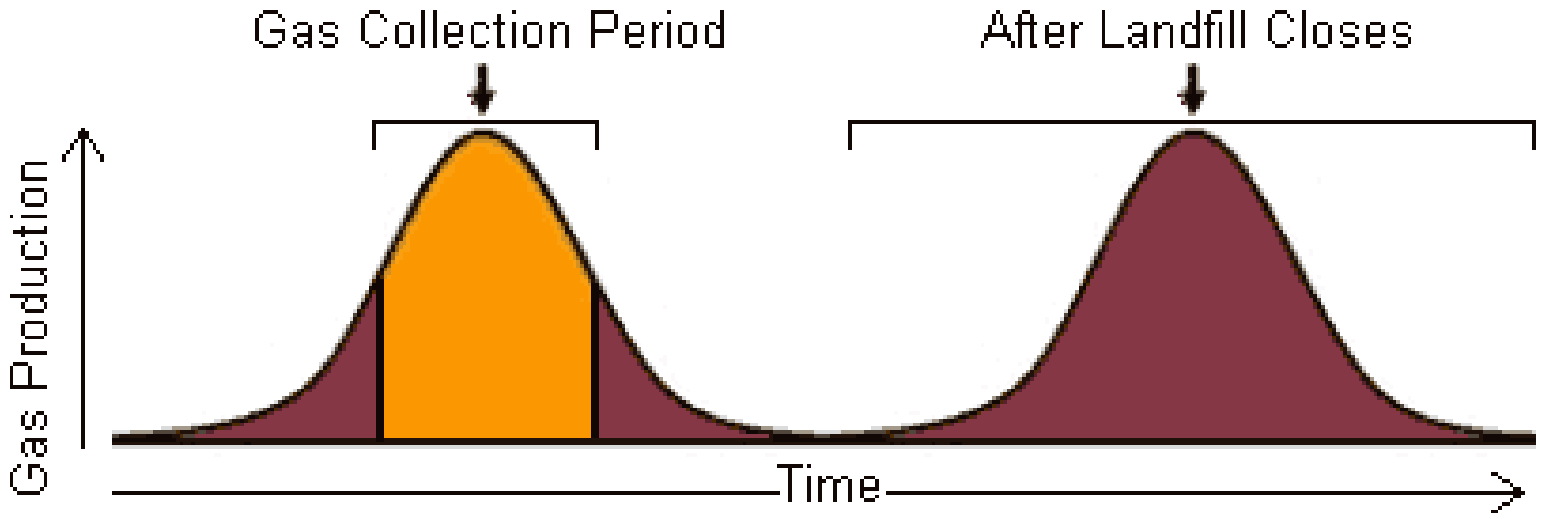
3) **<u>Once the gas is purified…</u>** it may be acceptable to burn it for steam or electricity, however, this may not be possible without mismanaging the landfill and releasing more gas. Other alternative technologies include piping it into natural gas lines, producing hydrogen or segregating the CO_2 and methane to be sold as industrial chemical feedstocks.

Landfill Gas – Proper Management

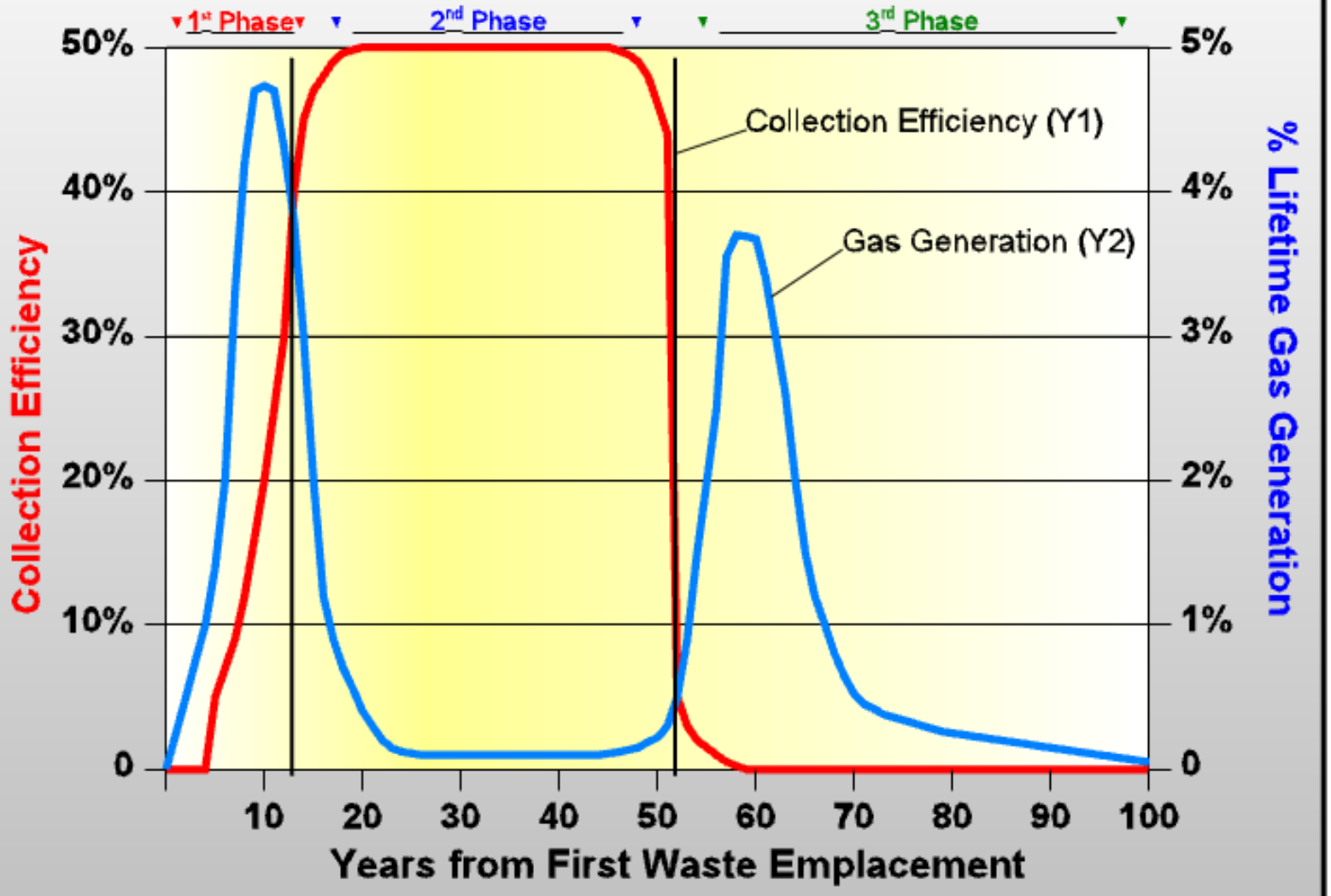
4) **Landfill gas use for energy should *not* be considered renewable**, since that allows it to compete with (and undercut) clean sources like wind power. Subsidizing landfill companies also puts source reduction, reuse, recycling and composting at a competitive disadvantage.

Landfill Gas: Only 10-15% Captured

- About ½ of landfills not required to capture
- About ½ of gas produced when no capture mechanism is in place
- About ½ of the gas collected when collecting gas



Gas Generation vs. Collection Efficiency



SOURCE: Center for a Competitive Waste Industry

More Gas = More Gas Leakage

- A study of women living near 38 New York landfills where gas is escaping found a significant four-fold increased risk of bladder cancer and leukemia.
- More exposure to methylmercury and hundreds of other toxins.

Landfill Gas & Global Warming

- Industry claims 95-99% capture rate in closed cells
- EPA researchers found 38-88% at the best landfills (the most well-managed ones where landfill operators volunteered to be studied)
- Front-loading methane generation = more methane leaking out sooner = global warming danger

Methane = 105 times more potent than CO_2 over a 20 year timeframe

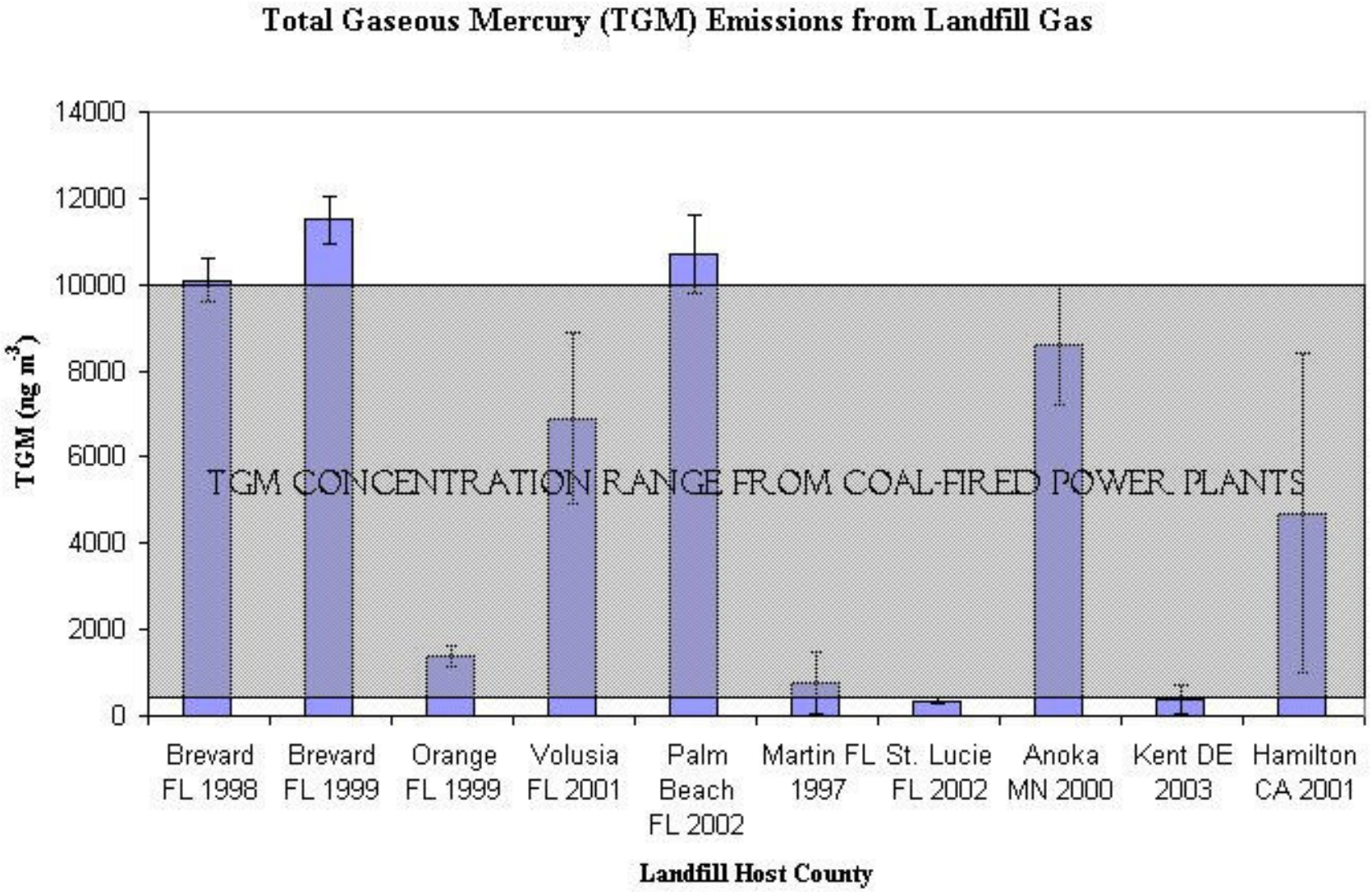
Bioreactors = Degrading the Cap

- Landfills are designed to be “dry tomb” facilities (avoiding moisture and gas generation).
- Wet landfills (bioreactors) cause accelerated decomposition
  - Creates more airspace so more waste can be dumped over time
  - Enormous and quick subsidence will crack cap
  - Replacing cap: $125,000/acre (who pays?)

Landfill Gas: Mercury

- Mercury Emissions Comparable to Coal Power Plant Exhaust
- Landfills are one of two known sources of *methyl*mercury (the fat-soluble kind)
  - Other source is sewage sludge
- Burning reduces it back to elemental mercury, but since most isn't burned, most escapes in its methylated form

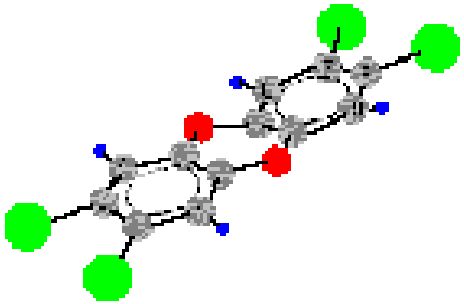
Landfill Gas: Mercury



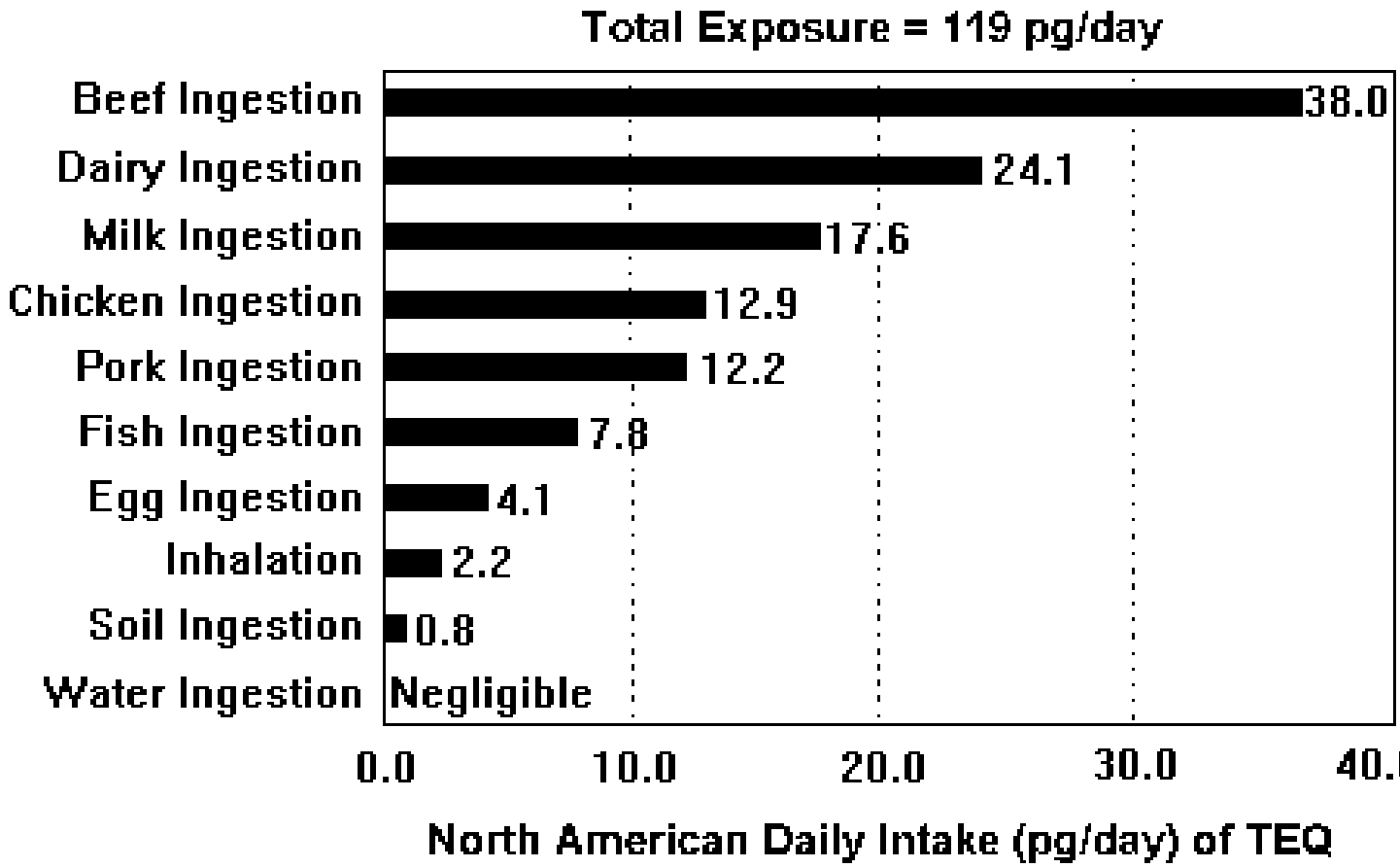
Dioxin Facts

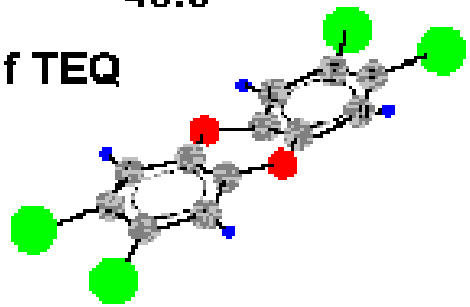
- Dioxins and furans are the most toxic chemicals known to science. They are highly toxic even in miniscule amounts.
- Dioxins cause infertility, learning disabilities, endometriosis, birth defects, sexual reproductive disorders, damage to the immune system, cancer and more.
- 93% of dioxin exposure is from eating meat and dairy products.

www.ejnet.org/dioxin/



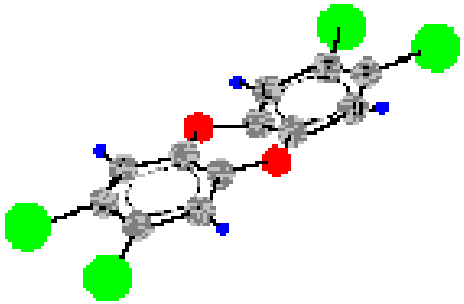
Exposure to Dioxins





How to make dioxin

- Dioxins are created by burning hydrocarbons (methane) with chlorine (present in landfill gas) in the presence of oxygen.
- Dioxin emissions increase when:
  - More chlorine is in the fuel/waste stream
  - Certain metal catalysts are present
  - The gases stay in a low temperature range (200-450^{o} C)



Renewable Fuel Standard (RFS2)

- Sets mandate for use of cellulosic ethanol and other “advanced biofuels”
- Not enough cellulosic ethanol to meet standard; RPS2 could collapse
- EPA’s way to keep it alive: subsidize landfills
- EPA aiming to allow landfill gas to energy technology to meet RFS2 obligations

Environmental Hierarchy of Waste Management & Energy Production Methods / Fuels / Technologies

Solid Waste Management

Cleanest ← → Dirtiest

Redesign	Toxics Use Reduction	Reduce Consumption	Reduce Packaging	Reuse	Recycle: Source Separate	Recycle: Recycle	Recycle: Downcycle	←Solutions Problems→ Compost	Landfill	Disposal / Dispersal: Deregulate	Disposal / Dispersal: Incinerate
Manufacturing	Reduction	Reduction	Reduction	Reuse	Separate			Compost			
Make products durable, recycled and recyclable Use materials which are more environmentally sustainable	Reduce amounts of toxic chemicals in production Replace toxic chemicals with less toxic or non-toxic alternatives	Use less Buy less Buy stuff with less packaging Avoid disposables & non-recyclables	Bring your own bag	Thrift stores Charity collection Dumpster diving Freecycle	Avoid mixing different types of materials		Recycling things into other products that can't be recycled – like paper into tissue paper	Anaerobic Digestion	Landfill Mine Fill Monofill	Land Application Beneficial Use Recycling toxic or radioactive wastes into consumer products or building materials	Mass Burn Co-firing Fluidized Bed Gasification Plasma Arc Pyrolysis

Electricity Production

Cleanest ← → Dirtiest

Conservation	Efficiency	Clean Renewables: Solar	Wind	Micro-hydro	Ocean	←Solutions Geothermal	Problems→ Hydroelectric	Dirty Energy: Natural Gas	Oil	Coal	Incineration	Nuclear
Lighting	Lighting Motors Appliances	The electric grid can be run 100% on intermittent technologies using storage strategies to balance the load. This can include flywheel energy storage, compressed air, molten salt, hydrogen, batteries or – until we're ready to remove them – hydroelectric dams.						Simple Cycle Combined Cycle Fuel Cell		Conventional Gasification ("Clean coal")	(see "biomass feedstocks" list below)	Fission [Fusion]

Transportation & Heating Fuels

Cleanest ← → Dirtiest

Conservation	Efficiency	Clean Energy: Clean Electricity	Clean Energy: Sustainable Biodiesel	Problems→ Biodiesel	Ethanol	Dirty Energy: Natural Gas	Landfill Gas	Oil	Waste-Based Fuels	Coal	Tires	Hazardous Waste
Mass Transit Carpooling Telecommuting Reduce Sprawl Trails-to-Rails Bicycling Walking Buy/Work Local	Fuel Efficiency Standards Hybrids Weatherization Ground- and air-source heat pumps	Plug-in Hybrids or Full Electric Vehicles; for heating, ground- and air-source heat pumps	From used vegetable oils or non-biotech algae *[can meet a very small portion of fuel demand]*	Soybeans Sugarcane Palm Oil	Corn-based ethanol Cellulosic ethanol (from biofuel feedstocks – see below)		Boiler Piped into natural gas lines	[and other petroleum products]	Trash / sludge-to-ethanol (cellulosic ethanol) Thermal de-polymerization	Coal-based liquid fuels	Cement Kilns Paper Mills	Cement Kilns Chemical Plants

Biomass / Biofuel Feedstocks

Least Dirty ← → Most Dirty

Digester Gas	Landfill Gas	Gases	Solids	Trees	Energy Crops	Agricultural Crop Residue	Paper / Lumber Mill Wood Waste	Animal Factory Wastes	Construction / Demolition Wood Waste	Sewage Sludge	Tires	Municipal Solid Waste
Sludge Animal waste Food waste				Tree Trimmings ("Urban Wood Waste") Forest Cutting	Phytoremediation plants Biotech			Poultry litter	Painted/treated wood			

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Zero Waste Hierarchy

- Rethink / Redesign
- Reduce
- Reuse
- Recycle
- Compost
- Research
- Stabilize (digest) / Monofill and manage properly

Zero Waste Hierarchy (1/6)

- Redesign
  - Make products durable, recycled and recyclable
  - Use materials which are more environmentally sustainable
- Reduce
  - Toxics Use Reduction
  - Reduce amounts of toxic chemicals in production
  - Replace toxic chemicals with less toxic or non-toxic alternatives
- Consumption Reduction
  - Use less
  - Buy less (reduce advertising)
  - Buy stuff with less packaging
  - Avoid disposables & non-recyclables
- Packaging Reduction
  - includes styrofoam bans and single-use paper/plastic bag bans and taxes

Zero Waste Hierarchy (2/6)

- Reuse/Repair
  - Thrift stores
  - Charity collections
  - Dumpster diving
  - Freecycle
  - Paint blending
  - Repair centers for bikes, computers/peripherals, furniture, appliances, etc.
- Recycle
  - source-separation, not single stream
  - seek the highest end-use and avoid "downcycling"; segregate office paper from lower paper grades and other recyclables, to keep quality high
  - buy recycled; create market for glass so that glass collected for recycling is actually recycled, not dumped in landfills
  - adopt a bottle bill / wastepicking

Zero Waste Hierarchy (3/6)

- Compost
  - Curbside collection of organics (weekly), which can be done while decreasing the collection of trash and recyclables to biweekly (the smelly stuff in trash is the compostable stuff, so this encourages people to compost if they don't want trash smelling).
  - Ban clean organics (not sewage sludge!) from landfills. Sewage sludge, even after being digested, does not belong on farm fields or in urban gardens.
  - Clean compost from food scraps and yard trimmings can be used in gardening or landscaping.
- Research
  - on a regular basis, do a waste sort and see what remains in the waste and feed that into Extended Producer Responsibility campaigns, product bans and other measures to eliminate these residual materials from the waste stream, ensuring that they're dealt with further up in this hierarchy

Zero Waste Hierarchy (4/6)

- “Dirty” Materials Recovery Facility (MRF) for the remainder
  - pull out additional recyclable and compostable material. It's important that this not be a replacement for source separation and upstream recycling, as it will get people out of their good recycling habits and will degrade the quality of recyclables, lowering their value and ensuring less will actually be recycled.
- Anaerobic digestion
  - The remainder, if there is enough organic material in it, should be digested in order to reduce the methane generating potential, stabilizing the waste
- Monofill (landfill in separate landfill cells at existing landfills)

Zero Waste Hierarchy (5/6)

- Ensure proper landfill management (don't mismanage the landfill by managing it for energy production)
  - Minimize gas production: Do not manage the waste facility as an energy facility by stimulating gas production.
    - Keep out liquids
      - Cover the active face of the landfill to keep out rainwater, using a temporary structure
      - Do not recirculate leachate
    - Cap landfills with permanent synthetic covers and install gas collection systems in months, not years.
  - Maximize gas collection:
    - Segregate organics in landfills for best gas collection
    - Maintain high suction on collection wells; do not damp down wells or rotate off the wells to stimulate methane production

Zero Waste Hierarchy (6/6)

- Clean the gas prior to use
  - Filter toxins in the gas into a solid medium like a carbon filter; containerized and store on-site.
    - Do not send to carbon "regeneration" or "recycling" facilities [they simply incinerate the captured chemicals, polluting the air]
- The purified gas can be used:
  - for heating purposes (burned in a high efficiency boiler),
  - piped into gas lines,
  - used to make alternative vehicle fuel,
  - used in fuel cells,
  - burned for electricity in a high efficiency turbine (less preferable to uses for heating), or
  - the CO2 and methane can be segregated and sold as industrial chemical feedstocks (but not for food industry use).

- Landfill gas-to-energy should not be considered renewable (That allows it to undercut clean sources like wind and solar and puts source reduction, reuse, recycling and composting at a competitive disadvantage.)

For more Info…

- Incineration:
  - www.EnergyJustice.net/incineration/
  - www.EnergyJustice.net/tires/
  - www.no-burn.org
  - www.GreenAction.org
- Landfills and Landfill Gas Burning:
  - www.EnergyJustice.net/lfg/
  - www.ejnet.org/landfills
  - www.beyondlandfilling.org
- Zero Waste:
  - www.EnergyJustice.net/files/technologies.pdf
  - www.ilsr.org/initiatives/waste-to-wealth/
  - www.grrn.org/zerowaste/
  - www.zwia.org
  - New Energy Justice zero waste page coming soon… email mike@energyjustice.net for resources by email until new page is up.

Energy Justice Network

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