Approaches to Reducing Methane Emissions (WTE vs. Landfill Gas)

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Why reduce methane (CH_4) emissions?

Methane is a potent GHG:

- 28 times more potent than CO2 on a 100 year time frame
- 84-87 times more potent than CO_2 on a 20 year time frame (IPCC)

Sources

- Anthropogenic
- Natural sources (wetlands and peatlands)

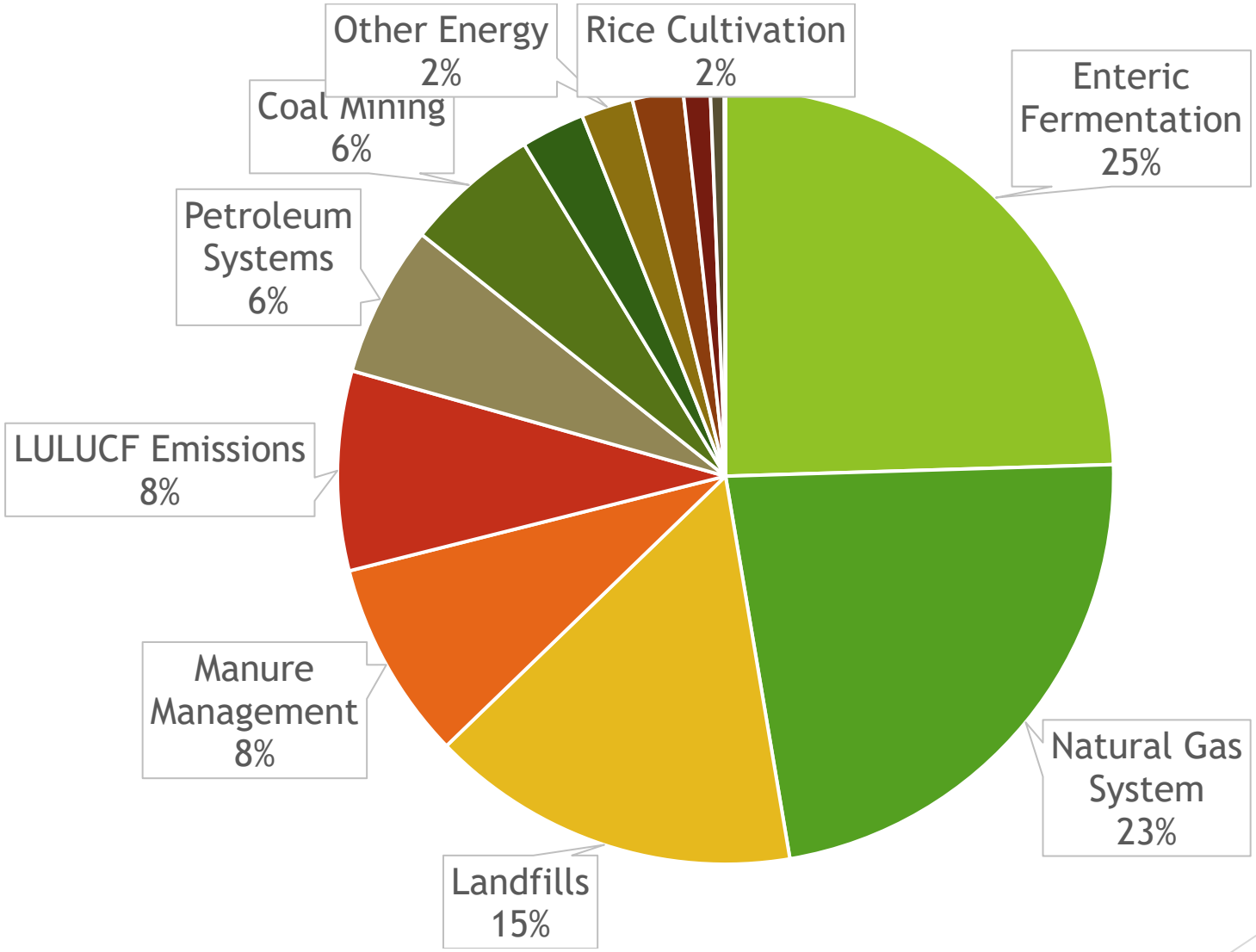
Methane is a source of energy

- Natural gas is predominantly methane (75-95%)
- When used as energy source-converts CH4 to CO_2

U.S Greenhouse Gas Emissions as reported by EPA in GHGRP, (MMT CO_2e) 2021 data



Methane Sources in US (EPA 2021 GHG Report)



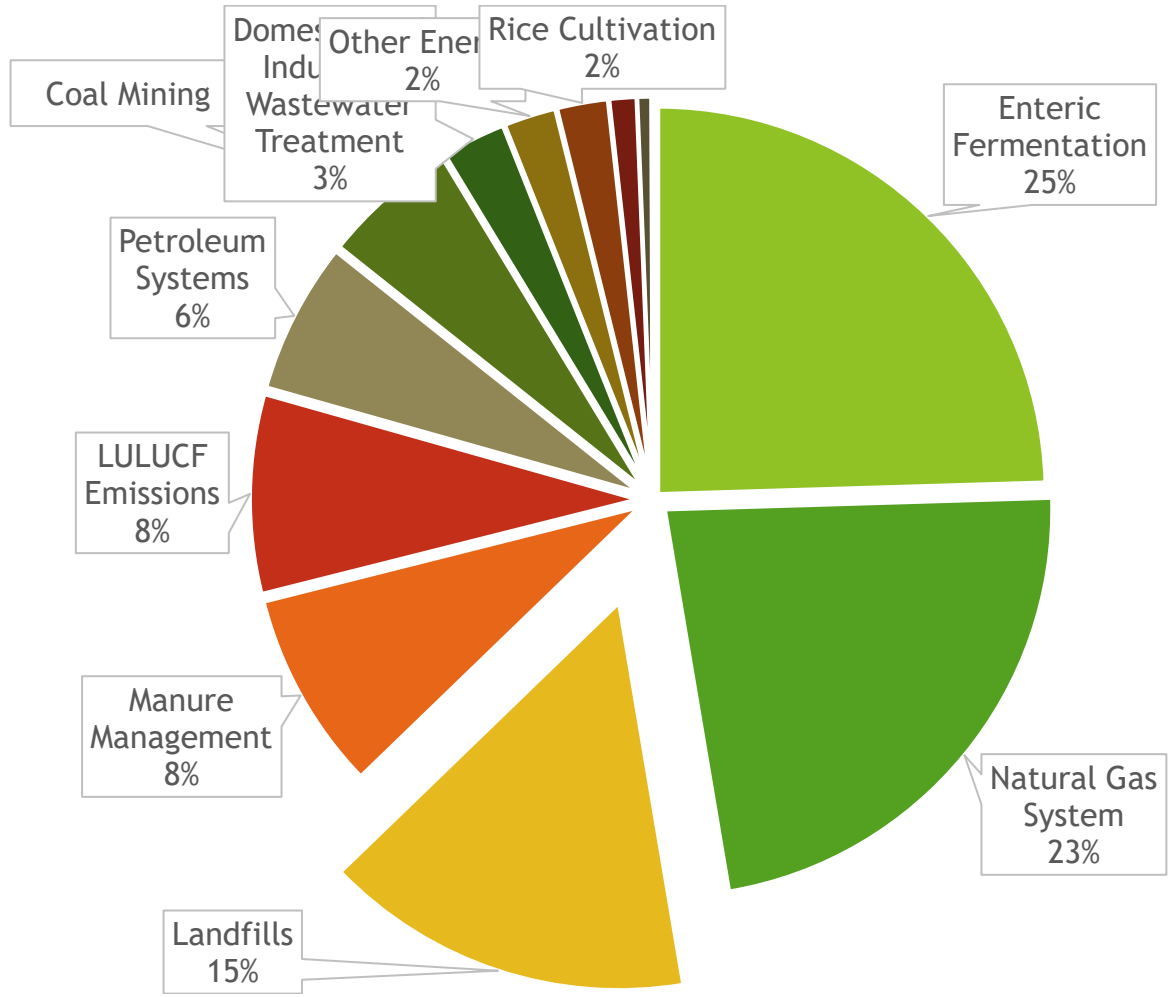
Take aways from data:

- Pursue emissions from largest emitters
  - Enteric Fermentation
  - Oil and Natural Gas
  - Landfills

Methane reduction policies: Is the U.S. on the right path?

- Significant policy focus to measure and reduce methane emissions in the oil and gas industry.
- EPA promulgated regulations on measuring and reducing CH_4 emissions, final rule announced December 2, 2023.
- Industry Efforts
  - Veritas (protocol for measuring methane emissions)
  - ONE Future (50 natural gas companies are members, collective methane intensity in 2023 was 0.42%, beating the 1% goal) https://onefuture.us/2023-annual-report/
  - EEI/AGA's Natural Gas Sustainability Initiative (NGSI) (aligns with ONE Future)

Landfill Gas CH_4 source



Landfills/MSW trends over time (MMT CO_2 Eq)

Activity	2005	2017	2021	% Change
MSW CH_4 Generation	303.7	327	334.8	10.2%
MSW CH_4 Recovered	-148.4	-192.9	-201.5	35.8%
MSW CH_4 Oxidized	-23.6	-28.6	-29.6	25.4%
MSW net CH_4 Emissions	131.7	105.5	103.7	-21.3%
Industrial CH_4 Generation	17.9	20.4	21	14.0%
Industrial CH_4 Oxidized	-1.8	-2	-2.1	11.1%
Total	147.8	123.9	122.6	-16.2%
MSW Volume(a) (MT)	254	269	292	15.0%

Comparison begins in 2005 when methodological calculation change occurred.(EPA, 2023).
a. Millions of tons of MSW as per Statistica, https://www.statista.com/statistics/186256/us-municipal-solid-waste-generation-since-1960/ only through 2018.

Landfill Management Practices



Given super emitters methane from landfills could be greater than estimated.



EPA Recommended improved prevention methods

- Composting
- Recycling
- Effective cover practices (may require pvc--not recyclable and future issue)



EPA and DOE provide reports on methods for capturing LFG



Little to no support for Waste-to-Energy (WTE)

Bipartisan Infrastructure Law & Inflation Reduction Act (IRA)

- Bipartisan Infrastructure Law
  - $275 million for Solid Waste Infrastructure for Recycling
- Inflation Reduction Act (IRA)
  - $5 billion for states, tribes, local governments
  - $68 million for low emissions electricity generation
  - $20 billion financial and technical assistance for projects that reduce or avoid GHG
  - $2.8 billion Environmental & Climate Justice Block Grants
    - Community-led air pollution monitoring, prevention and remediation
- Little allocated for WTE

Life Cycle Analysis of Energy Derived from MSW versus LFG

Analysis conducted by Ozge Kaplan, Joseph Decarolis, and Susan Thorneloe

- Environmental Science Technology 2009, “Is it Better to Burn or Bury Waste for Clean Electricity Generation?”

High-level assumptions in Review:

- Carbon intensity for collecting the MSW to the landfill same for WTE or LFG to energy (LFGTE)
- Emissions for the equipment for both the WTE and LFGTE insignificant and similar and therefore were not included
- Carbon intensity compared also to coal, natural gas, oil and nuclear, not including for this discussion.

Burn or Bury (Kaplan) assumptions cont.



MSW Assumptions:

MSW consists of post consumer recyclables

WTE System efficiency of 19%

Included production of limestone in scrubbers, and ash disposal in Life Cycle Inventory (LCI)



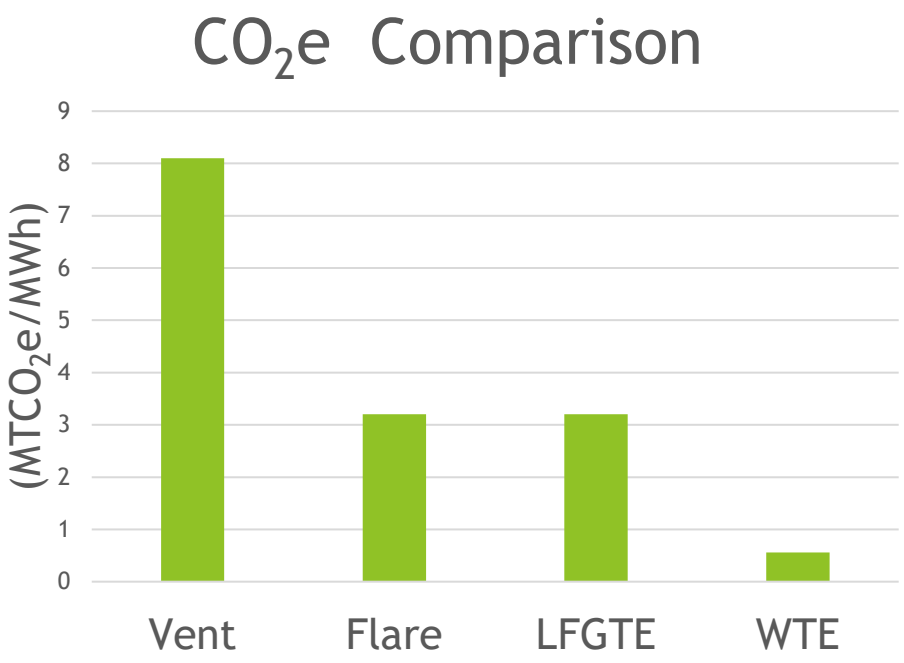
LFG Assumptions:

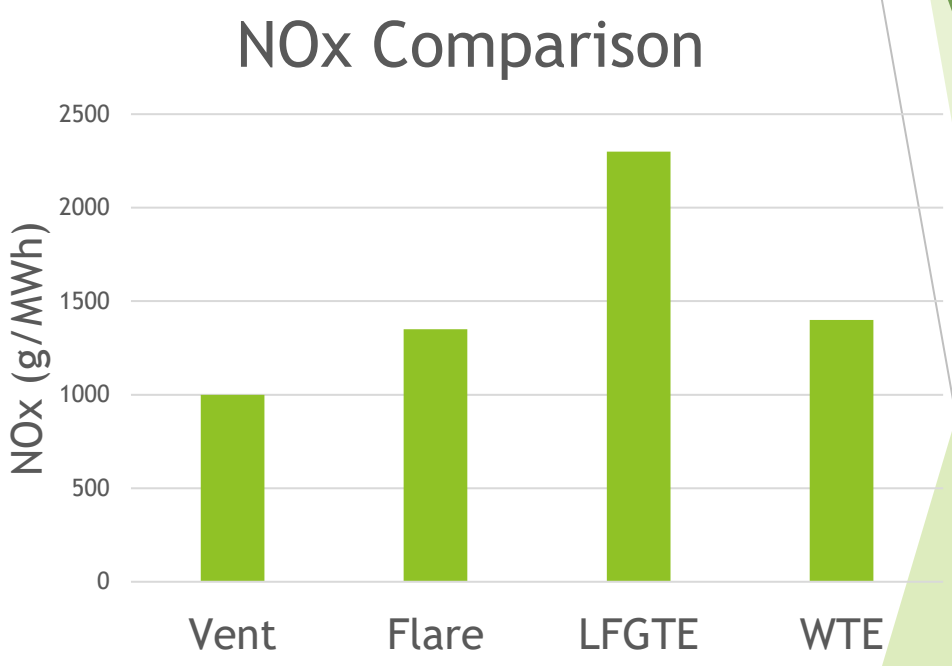
Decay of MSW over 100 years

LFG collected after two years, gas used to operate an internal combustion engine (ICE) for 60 years.

LFG collection efficiency at 80%, Oxidation at 15%

Burn or Bury Comparison Results (2009)





Other key findings (Kaplan et. al. 2009)

- WTE generates an order of magnitude more electricity than LFGTE
- 166 million tons/year
  - WTE can produce about 100 TWh or 600kWh/ton MSW
  - LFGTE can produce about 10 TWh or 65 kWh/ton MSW



2020 MSW Energy Recovery Technology Report for EPA

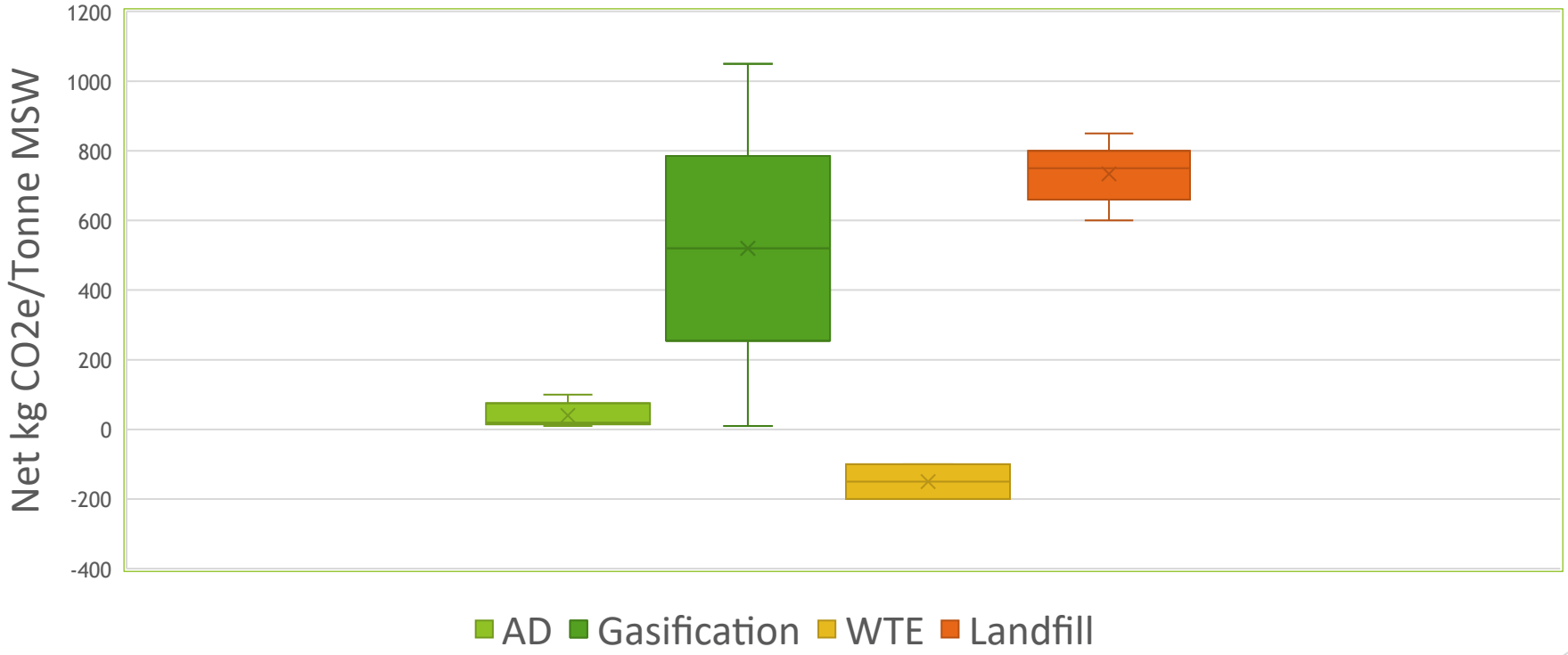
Report by Susan Thorneloe, et al, including Ozge Kaplan—similar team as 2009.

- Reviewed relevant peer-reviewed Energy Recovery Technology Publications and existing technologies in operation.
- Technologies Reviewed both in ground and peer reviewed papers
  - Conventional WTE
  - Gasification
  - Pyrolysis
  - Anaerobic Digestion (AD)
  - Landfill Gas to Energy

Summary of the technology options

- Conventional WTE (remove recyclables, some processing for use in boiler to produce steam, generate electricity, Rankine cycle).
- Gasification: partial oxidation of the MSW to produce gases that may be combusted for electricity production or gases further processed to create other products (liquid fuels, chemicals).
- Pyrolysis: decompose the carbon with heat absent oxygen.
- Anaerobic Digestion (AD): decompose organic material into methane and CO_2 by microorganisms in an anaerobic environment.
- Landfill Gas to Energy: gather, clean and boost the gas from a landfill to then use for energy purposes.

Net CO_2e emissions from MSW Feedstock (Thorneloe et al. 2020)



Thorneloe Results for the EPA Study (2020)

- WTE Conventional Technologies:
  - Provide greater energy savings compared to gasification and landfill gas to energy (ferrous and non-ferrous metal recovery provides greater savings),
  - Require less net water consumption
  - Lower CO_2e emissions (GRAPH)
  - Lower solid residues generated (except compared to landfill gas to energy)

Other findings

Cost data highly variable and therefore did not have high confidence to compare

Feedstock variability significant

More guidance needed for permitting requirements

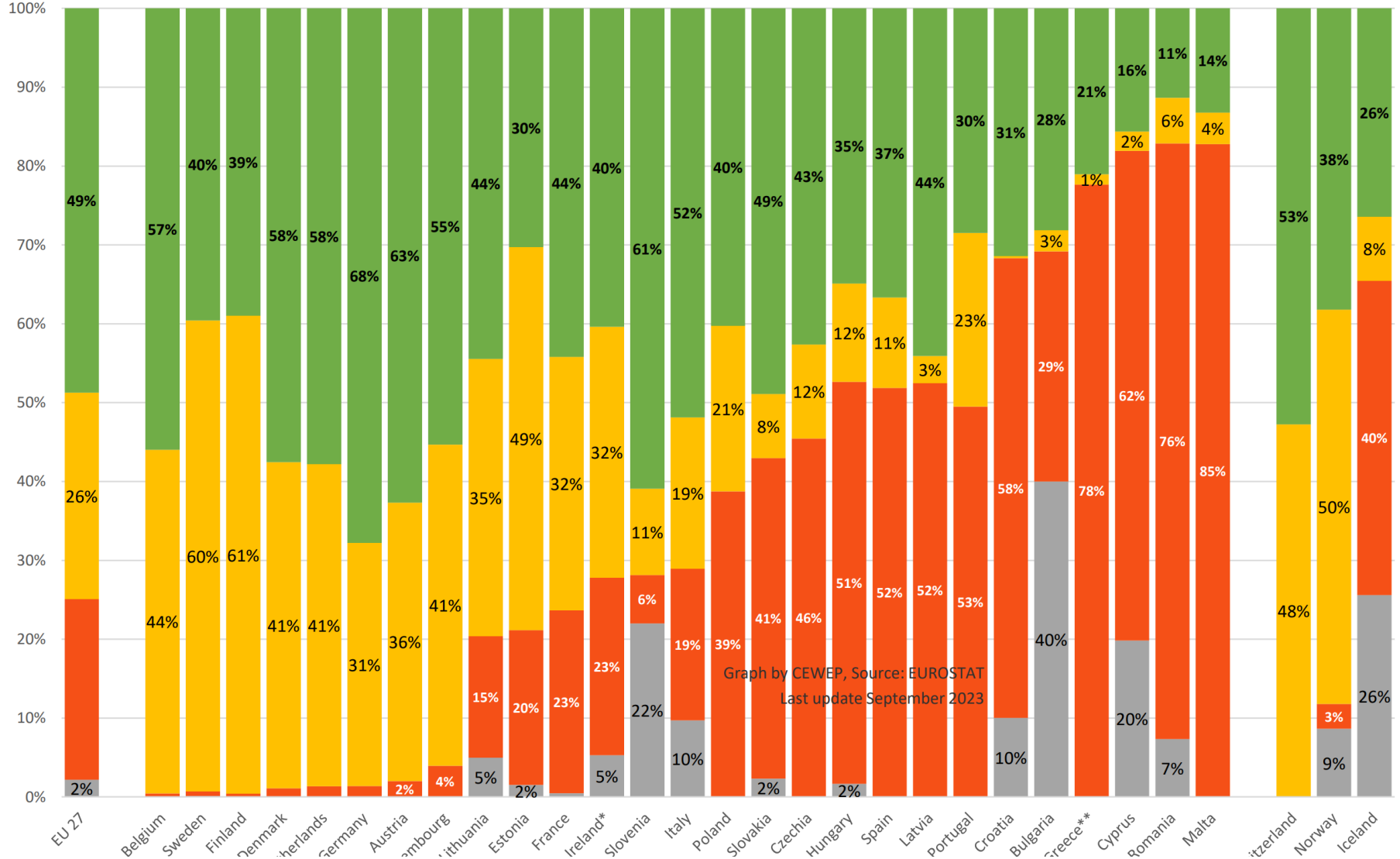
Europe has close to 500 WTE facilities totaling approximately 5.1 GW (Statistica)

United States has 73 WTE facilities operating.

Further Analysis needed to determine U.S. barriers

- Lack of Political acceptance/leadership?
- Tax and permitting policies?

Municipal waste treatment in 2021



Landfill
Waste-to-Energy
Recycling +Composting
Missing data

CEWEP

Percentages are calculated based on the municipal waste reported as generated in the country

*: last available data 2020
**: last available data 2021

Policy Approach

- EPA (and Congress) focus on landfill gas: not MSW before going to landfill
- DOE Funding not as focused on WTE

- What is driving policy approach to use landfill gas and not MSW?
  - Requiring it to be organic?
  - Challenge to have MSW feedstock approved under the Renewable Fuel Standard.
  - Concern that non-biobased materials used, such as non-recycled plastics.
  - Landfill gas has only bio-organic materials.
  - Historical emission problems with early facilities?
  - Is perfection creating barriers to dramatic GHG reductions?

Potential Arguments

Landfill gas to energy:

- Only biogenics
- Sequester the carbon—but do we?

What about micro-plastics?

- Might it be better to use the plastic?
- Benefits of the plastic BEFORE going to waste
  - Food preservation
  - Medical (COVID vaccines?)

Microplastics (briefly)

- Are the plastics “caught” for sequestration?
- “Some of this environmental pollution is from littering, but much is the result of storms, water runoff, and winds that carry plastic—both intact objects and microplastics—into our oceans. Single-use plastics—plastic items meant to be used just once and then discarded, such as a straw—are the primary source of secondary plastics in the environment.” (National Geographic)
- Comprised of cigarette butts, clothing residue, landfills, runoff.
- “In the last not even one hundred years–mostly since the 1950s–we as humans have produced 8 billion tons of plastic, and the estimate is only about ten percent of that has been recycled,” Shemitz says. “So where do microplastics come from? It comes from all of our stuff.”

Carbon emissions reduced from plastic

- Plastic provides food preservation—reducing food spoilage and CH_4 emissions
- Agriculture film
  - Reduces amount of fertilizer required (lower GHG emissions)
  - Reduces amount of water required (helping with water scarcity and energy to draw on water)
- Columbia University Report (2011) only 15% of plastic is recycled.
  - Lastly, increased WTE capacity would reduce the carbon footprint of waste management in the U.S. For example, a 25% diversion of mixed biomass and NRP in MSW from landfills to new WTE facilities will result in greenhouse gas (GHG) reduction of 35 to 70 million tons of carbon dioxide equivalent, depending on the degree of landfill capture in present landfills.
- Drawing on non –recycled plastics for energy could displace fossil fuels, reduce micro-plastics and provide electricity.

Questions?

Landfill Gas GHGRP Methodology

- GHGRP approach for estimating landfill gas emissions (EPA 2023, p. 7-7)
  - Directly reported by the landfills
  - Scale-Up factor for facilities not subject to GHGRP
- Rocky Mountain Institute Report
  - Methane capture at landfills varies widely
  - Significant super emitters as shown by Carbon Mapper
  - Focus on measuring the landfill gas, still there are leaks

EPA Waste Reduction Model (WARM)

- Anaerobic break down of organic material creates CH4 and CO2
- CH_4 considered anthropogenic
- Organic material that does not decompose considered a Carbon sink
- Stored non-organic (plastics) not considered a sink
- Emissions and sinks depend on waste material.

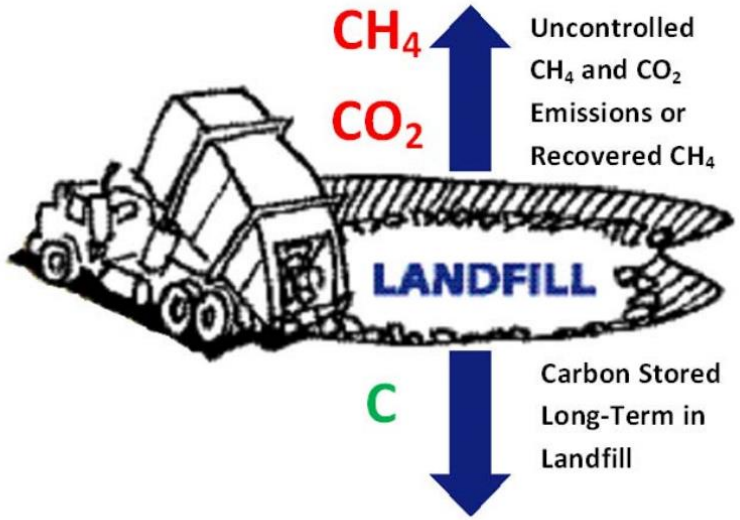
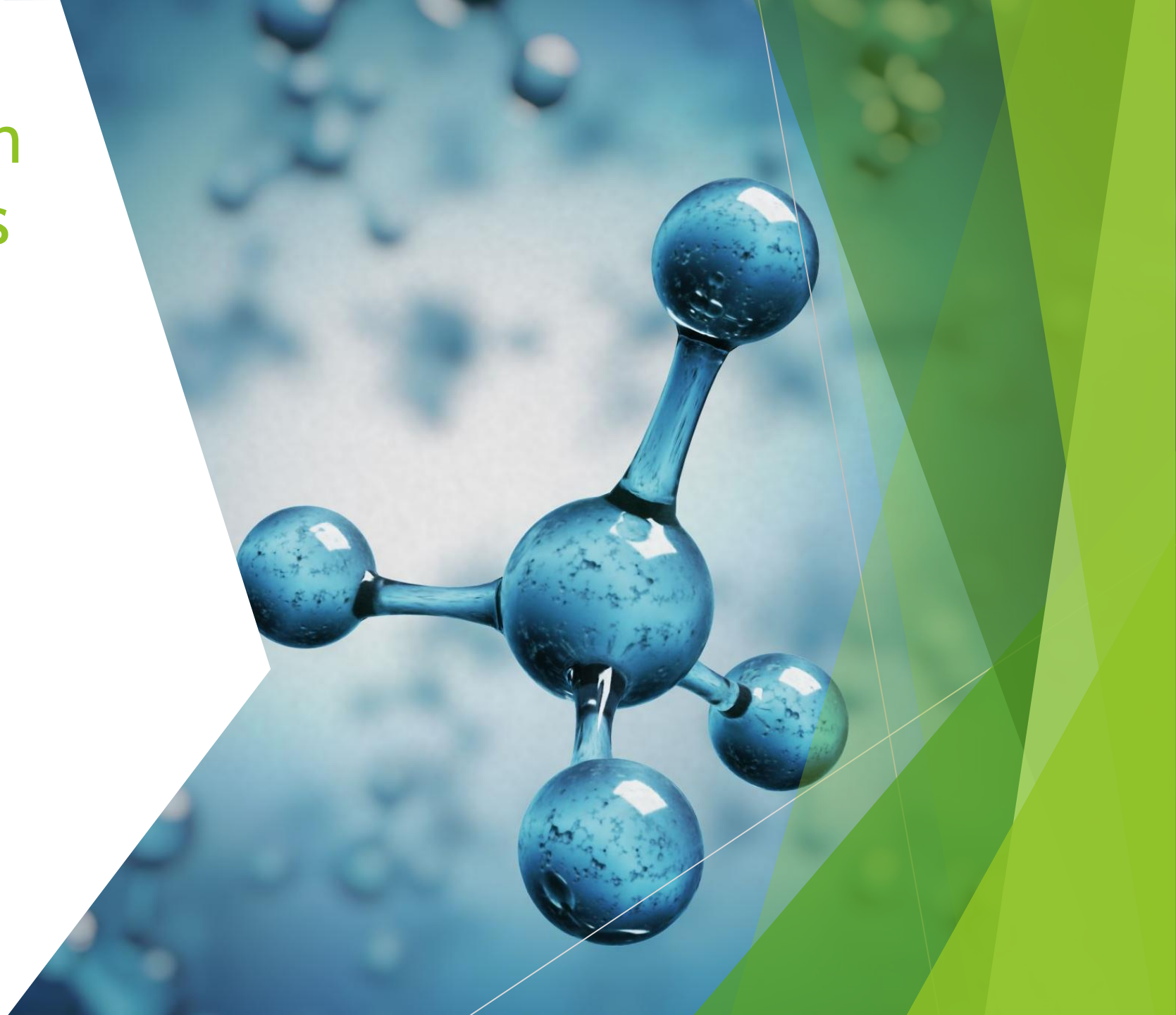


Diagram taken from EPA Landfill Carbon Storage in WARM October 27, 2010

Methane Emission Reduction Efforts

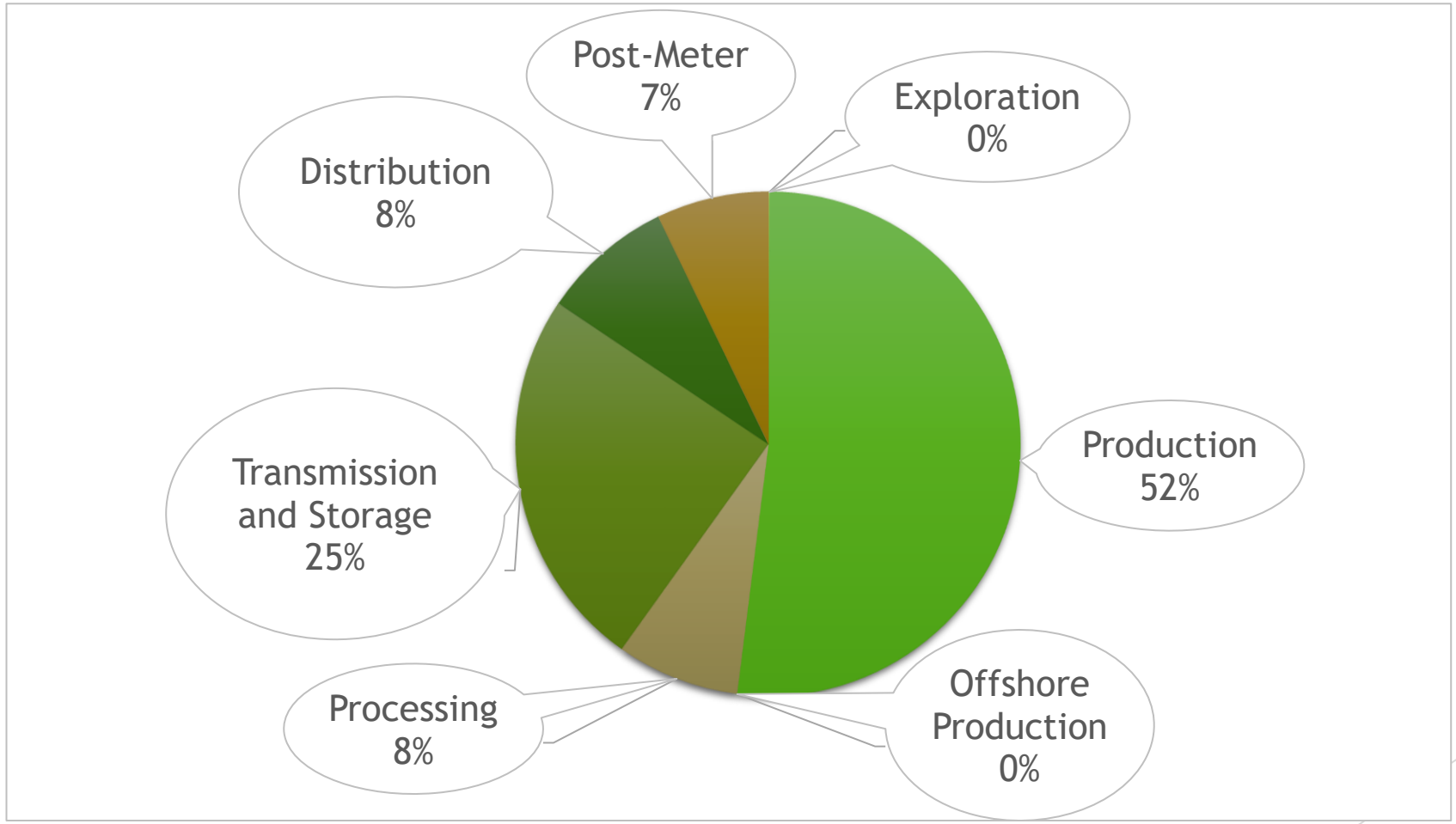
- Natural Gas Industry
  - Industry led efforts
  - Significant Regulations
- Enteric Fermentation
  - Some promising research
  - Sector that needs more effort
  - Careful regarding food and economic security



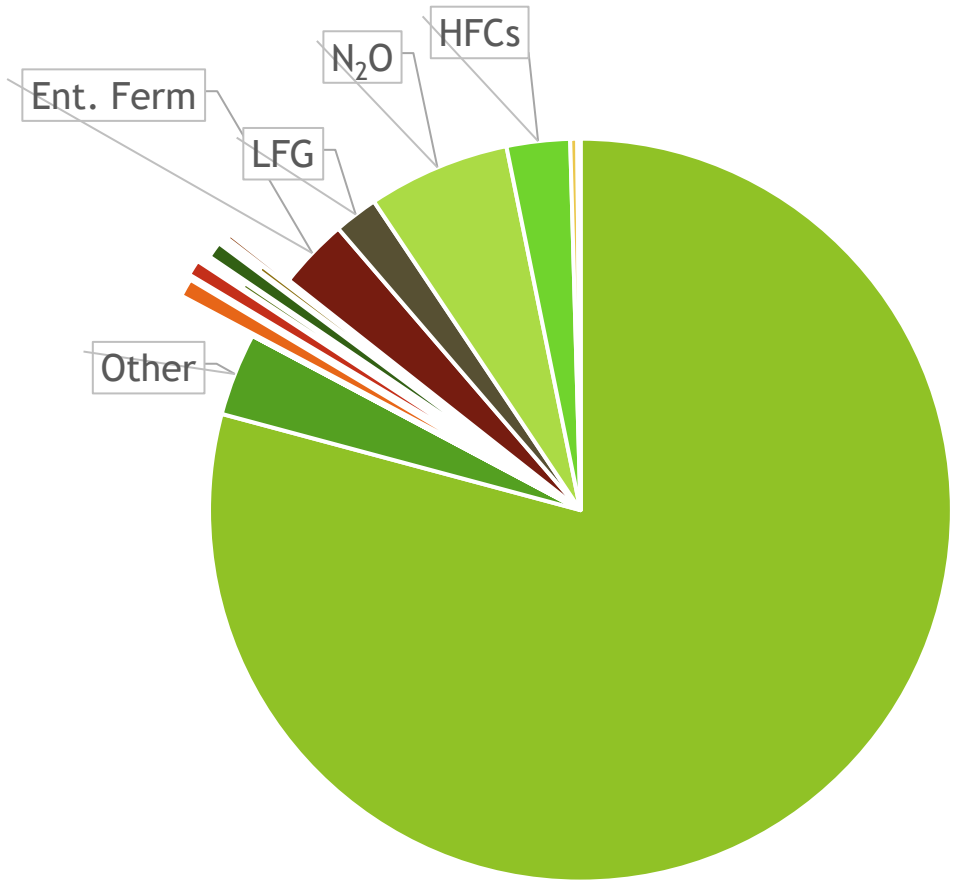
Methane Reduction Efforts Cont.

- Landfill Gas
  - Administration Efforts significant
  - WTE provides tremendous potential
- WTE Findings by Kaplan, Thorneloe and Columbia University Studies
  - Greater GHG reductions than LFG
  - Recover ferrous and non-ferrous metals
  - Reduce Landfill
  - Provide needed electricity

Looking at just Natural Gas Industry Methane Emissions CO_2e (Recall it is 2.65% total)

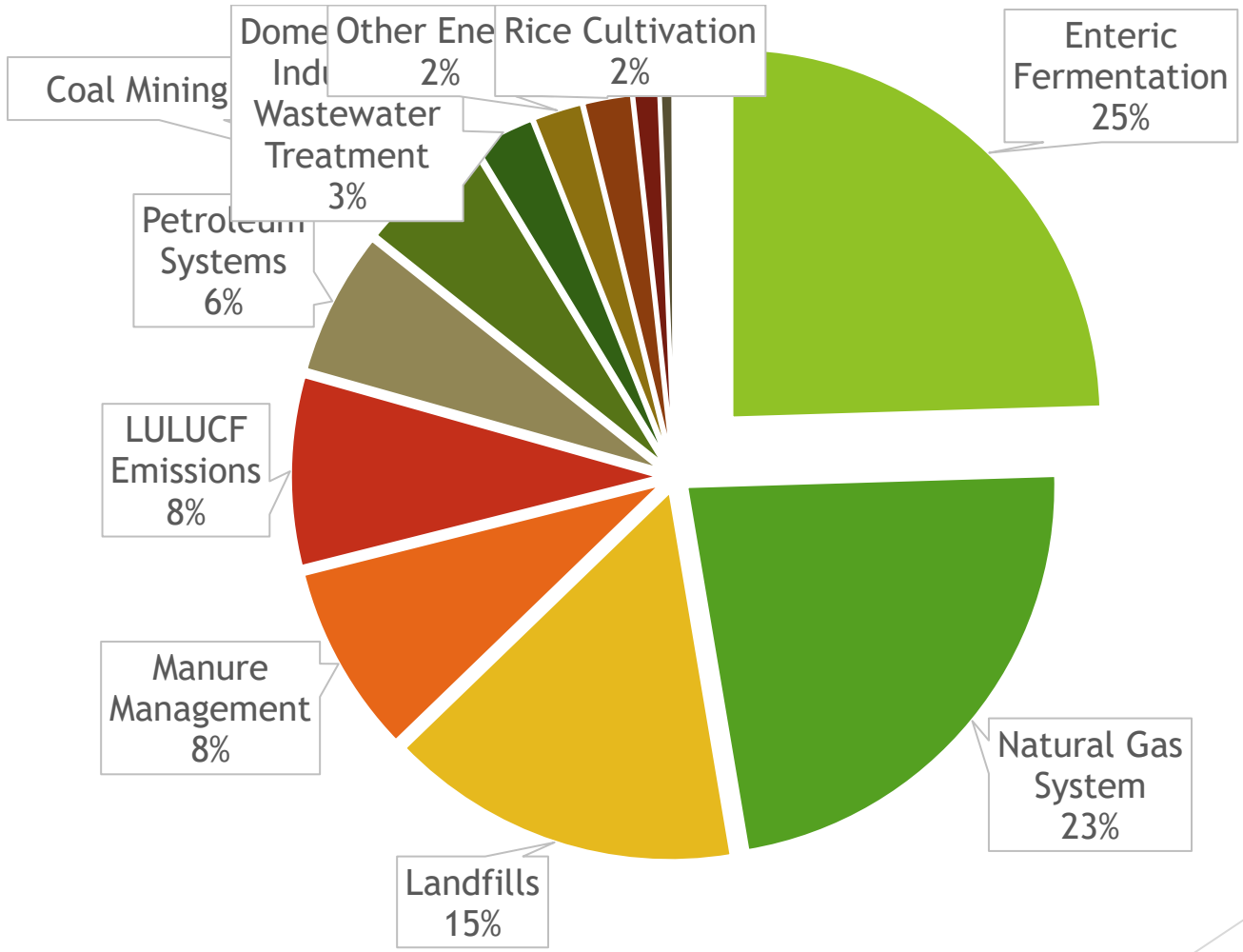


Natural Gas CH_4 Emissions Vs. All Emissions



- CO2
- CH4c Other
- Exploration
- Onshore Production
- Gathering and Boosting
- Offshore Production
- Processing
- Transmission and Storage
- Distribution
- Post-Meter
- Enteric Fermentation
- Landfill Gas
- N2Oc
- HFCs
- Other
- SF6
- NF3

Enteric Fermentation highest US CH_4 source: (2.8% overall)





Animal Rumination

- Reports provided by USDA and peer reviewed articles (Dillon, et al. 2021; AgLEDx with access to working papers)
- Measuring methane from livestock is evolving
  - Direct (expensive, point sources, limitations)
  - IPCC
- Factors affecting enteric fermentation (AgLEDx)
  - Feeding strategies and diet composition
  - Species type
  - Animal age
  - Environmental Stress
  - Other

Methods to Reduce Enteric Fermentation

Modify animal diets

- Improve feed quality with plant based products
- Provide additives; Asparagopsis taxiformis (seaweed)
  - Shown to reduce by 80% or more.
  - More research required regarding sustainability, feasibility and long-term effects.

Challenges

- Nutrition modifications can reduce animal nutrients and productivity.
- Costs may not be affordable
- Feed production could be an additional source of GHG emissions.

Enteric Renumeration Strategies, cont.



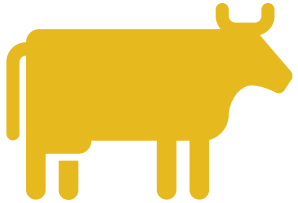
Genetic breeding—less research (Dillon, et al. 2021)

Breed animals that have naturally lower CH_4

Breed more productive animals

Gene editing

Breed to local conditions/environment



Herd Composition: reduce less productive animals

Animal nutrition provides food security

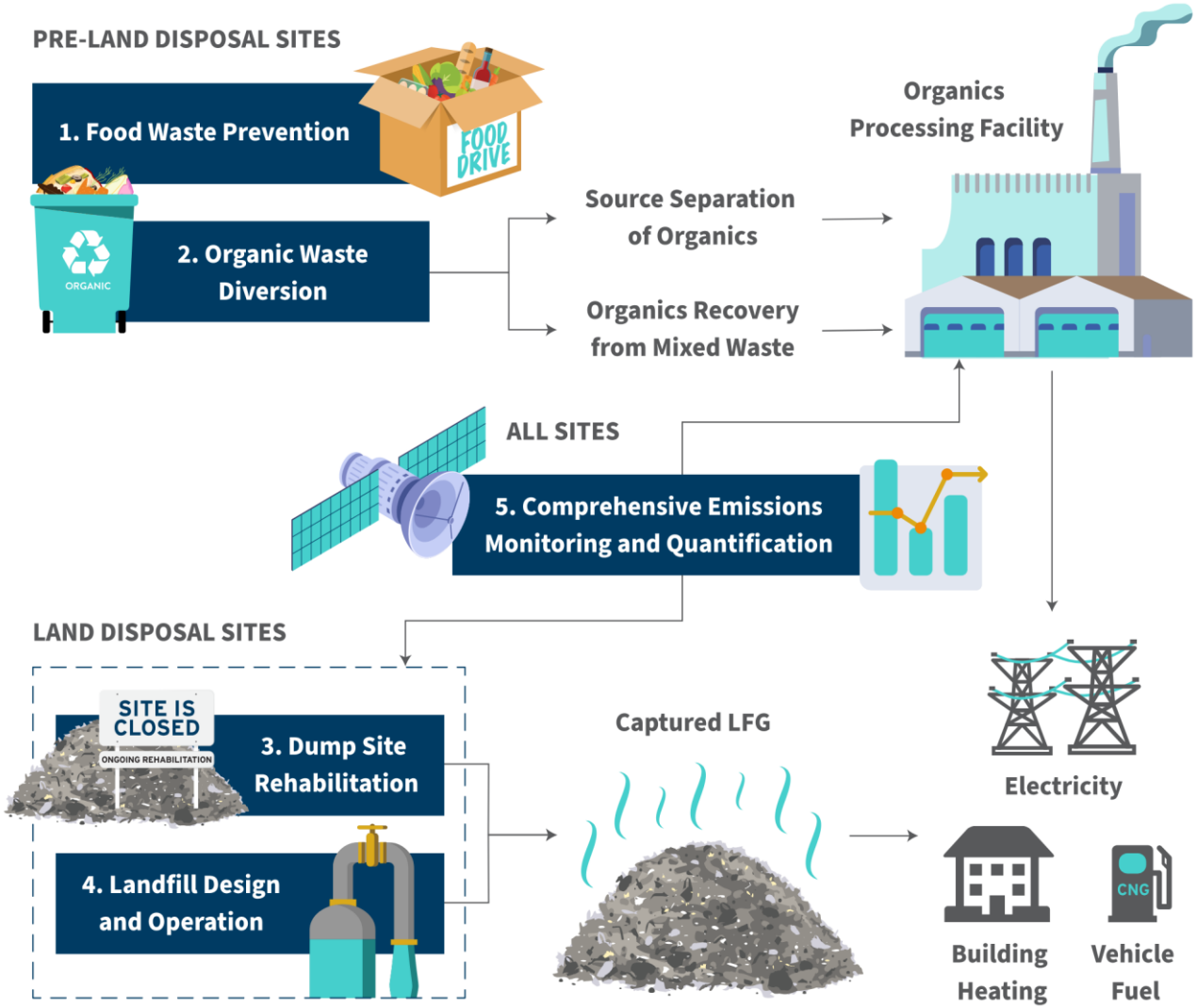
Padmakumar Varijakshapanicker, et al. 2019.

- Animal sourced foods provide nutrition
  - Reduce malnutrition in low- and middle-income countries,
  - Could help reduce obesity in higher income countries by replacing “empty calories”
- Livestock assist with United Nations Sustainable Development Goals
  - Convert human-unusable energy into highly nutritious animal-sourced foods.
  - Provide economic livelihoods
  - Provides environmental benefits in some regions

Peatlands (if time, recognize challenge)

- Peatland a significant source, approximately 40%, of CH_4
- Tradeoff of CO_2 and CH_4 emissions:
  - Feng and Adbdalla publications find that Increase impacted by both surface temperature and water table elevation;
  - As temperatures increase, apparent trend in methane emissions from northern peatlands/tundra;
  - Huang, Y, and Ciais, P. et al find a net INCREASE in GHG from lowered peatland water table.
- Further analysis needed to more thoroughly understand the CH_4 dynamics to determine what mitigation strategies may be available.

Landfill CH_4 Emissions Reduction Strategies (RMI)



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Sanitary Landfill

