U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Promising Approaches for Reducing Methane Emissions in the United States

Presenters:

Beau Hoffman, U.S. Department of Energy, Bioenergy Technologies Office

Dr. Hao Cai, Argonne National Laboratory

Anelia Milbrandt, National Renewable Energy Laboratory

Jason Feldman, Green Era Sustainability

Feedstock | Algae | Conversion | Systems | Data

April 20, 2022

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About the Bioenergy Communicators (BioComms) Working Group

Sponsor:

- U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO)

BETO & DOE National Laboratory Members:

- Bioenergy communicators, laboratory relationship managers, BETO tech team, and education and workforce development professionals

Purpose:

- Communications strategy for BETO-funded bioenergy research and development

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Today's Agenda

I. Beau Hoffman: DOE BETO Support for Reducing Methane Emissions
II. Dr. Hao Cai: Reducing Methane Emissions Via Waste-To-Energy Technologies
III. Anelia Milbrandt: Opportunities to Reduce Methane Emissions for Communities
IV. Jason Feldman: Welcome to the Green Era

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Today's Presenters

Beau Hoffman
Technology Manager
Bioenergy Technologies Office

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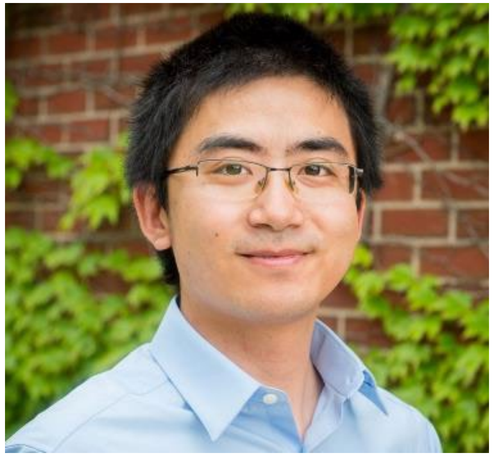

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Jason Feldman
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greenerachicago.org

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Technology Manager

DOE BETO

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DOE BETO Support for Reducing Methane Emissions

Beau Hoffman, Technology Manager
U.S. Department of Energy, Bioenergy Technologies Office

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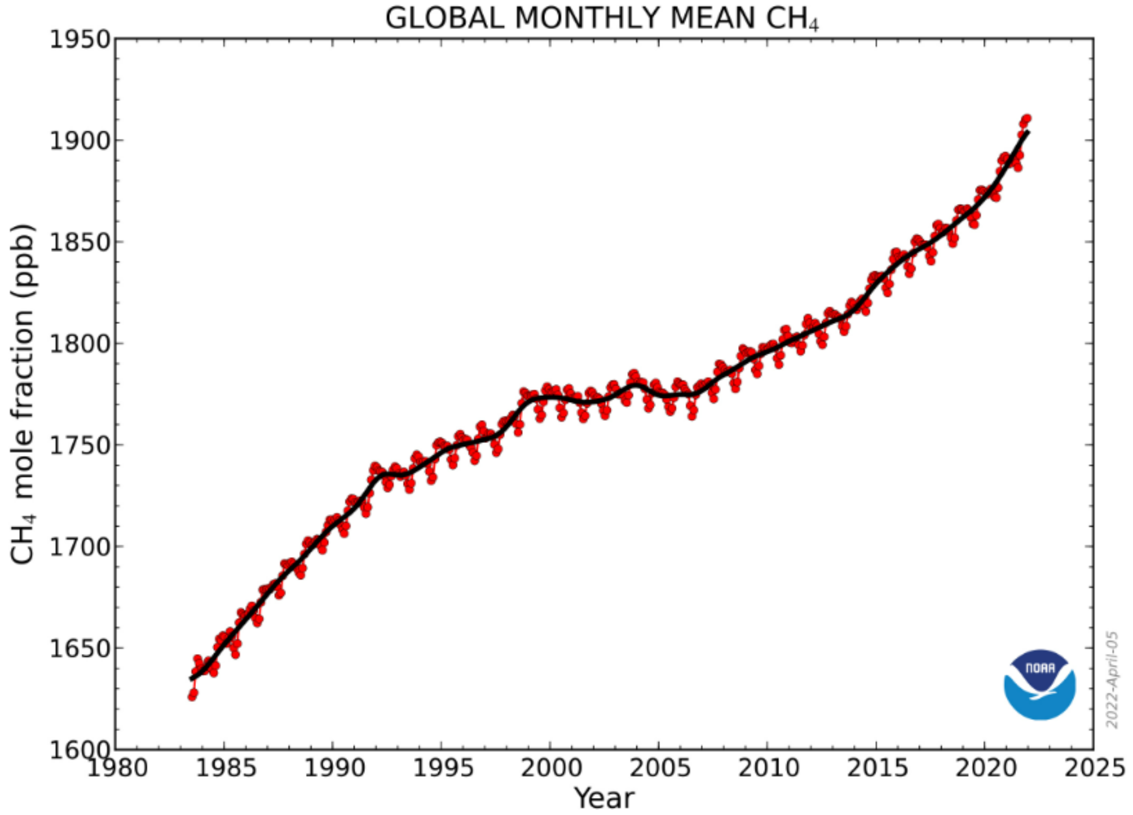
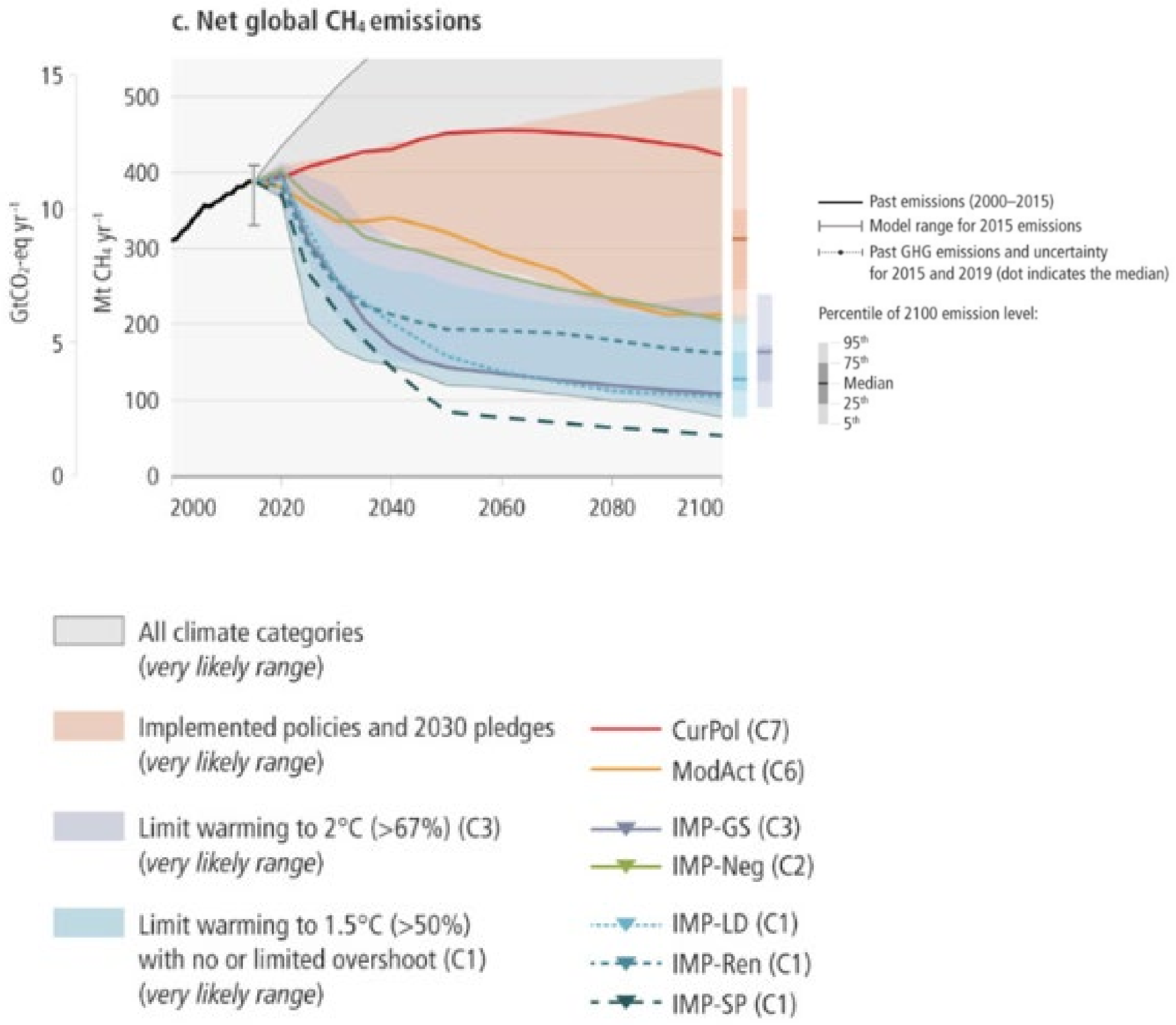
Increase in atmospheric methane set another record during 2021

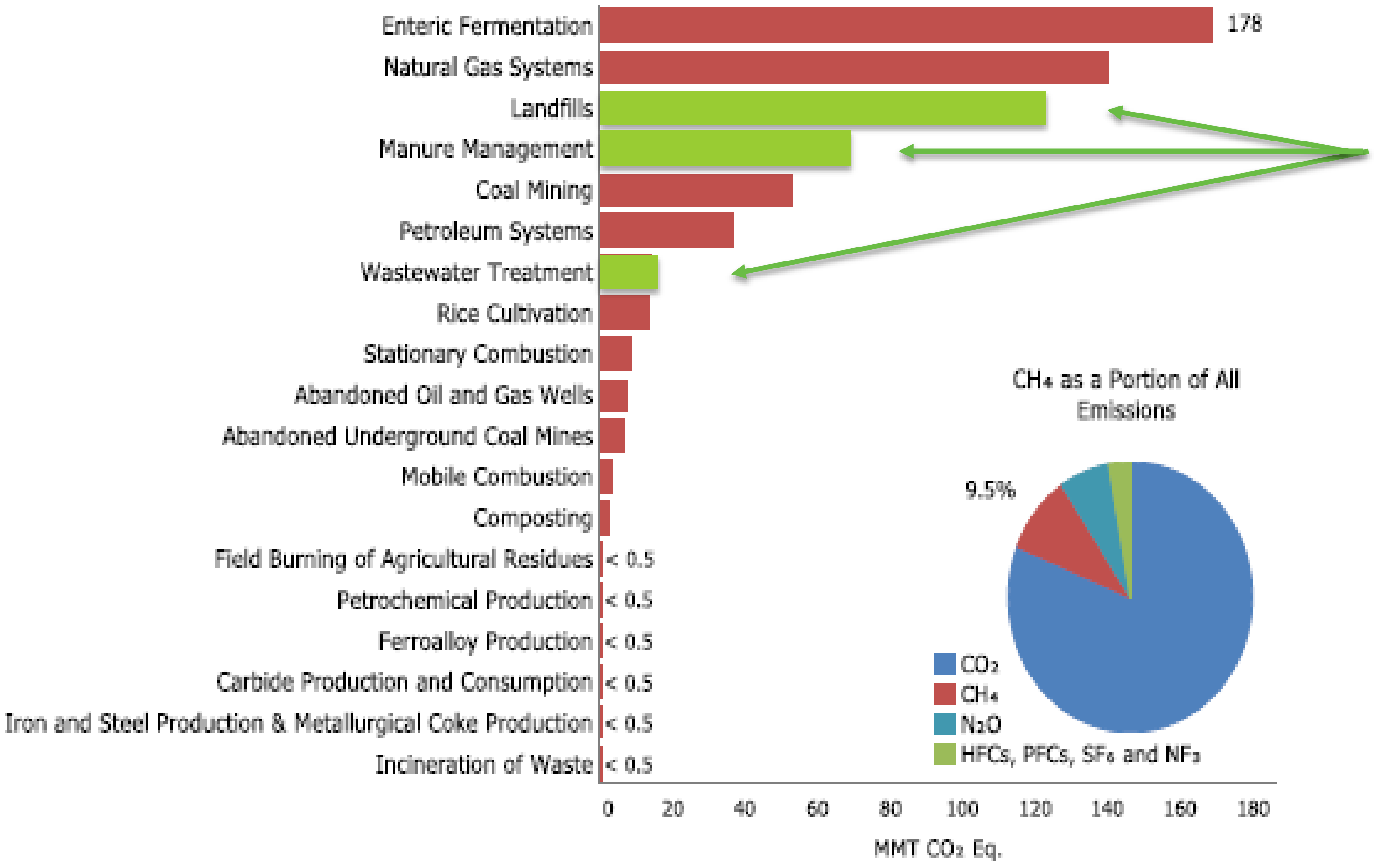


Source: NOAA Global Monitoring Laboratory



Source: IPCC (2022) Figure SPM.5.

Environmental Impacts of Organic Waste Processing



>230 MMT CO_2e/yr greenhouse gas (GHG) emissions (CH_4, NO_x, CO_2)

- Landfills are the 3rd largest source of CH_4 emissions nationwide, (114 MMT CO_2e/yr)
- Between 2020 and 2060, the number of available landfills will have decreased by 69%
- Organic waste landfill bans have been implemented in >7 states, many communities have also implemented targets or zero waste goals

CH4 = methane | CO2 = carbon dioxide | HFC = hydrofluorocarbon | MMT = million metric ton | NF3 = nitrogen trifluoride | NOX = nitrogen oxides | N2O = nitrous oxide | PFC = perfluorochemical | SF6 = sulphur hexafluoride

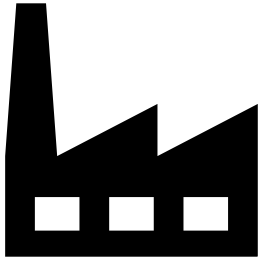
Source: epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Sources of Organic Waste in the United States

Food Waste

Discarded food from residential, commercial, institutional, and industrial sources

91 lb/per person (pp)/yr



Sewage Sludge

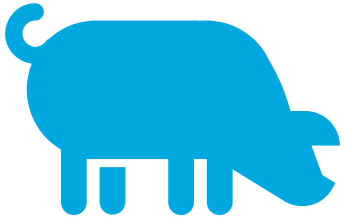
Solids remaining after wastewater processing

90 lb/pp/yr

Animal Manure

Organic material from concentrated animal feeding operations (e.g., dairy, swine)

240 lb/pp/yr



Fats, Oils & Greases

Animal byproducts and grease from food-handling operations (e.g., used cooking oil, animal fats, trap grease)

37 lb/pp/yr

(all numbers in dry lbs)

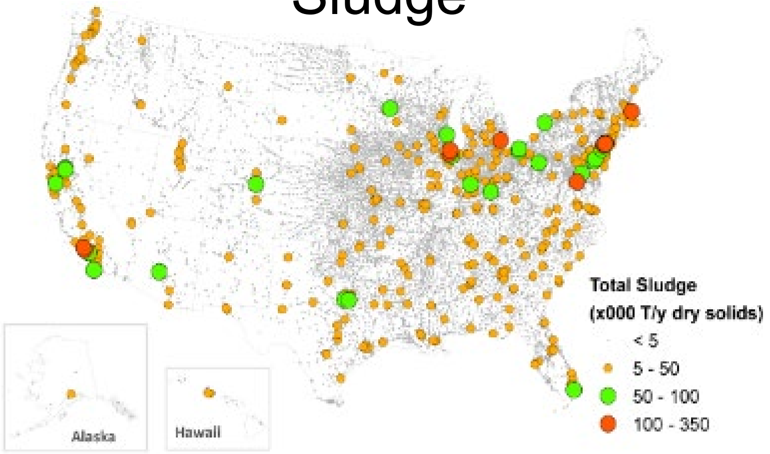
Distribution of Organic Waste

Wet Resources	Annual Beneficial Utilization (Current): Estimated Resource Availability (MM Dry Tons)	Inherent Energy Content (Trillion Btu)	Fuel Equivalent (MM GGE)[2]	Annual Potential Excess[1]: Estimated Resource Availability (MM Dry Tons)	Inherent Energy Content (Trillion Btu)	Fuel Equivalent (MM GGE)[2]
Wastewater Residuals	7.12	107.6	927.0	7.70	130.0	1,119.6
Animal Waste	15.00	200.2	1,724.3	26.00	346.9	2,988.7
Food Waste	1.30	6.8	58.2	14.00	72.8	627.1
Fats, Oils, and Greases	4.10	147.4	1,269.3	1.95	66.9	576.6
Total	27.52	462.0	3,978.8	49.65	616.6	5,312.0

[1] Unused excess in this definition includes landfilled biosolids and other wet resources.

[2] 116,090 Btu/gal. This does not account for conversion efficiency.

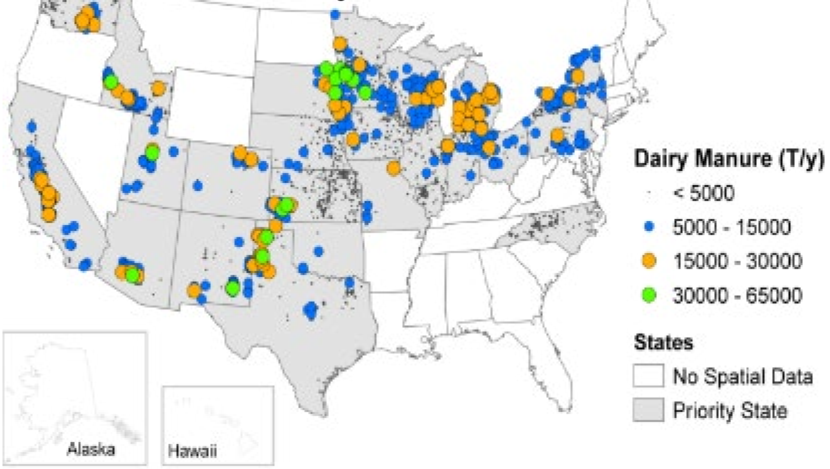
Sludge



Food Waste

Yellow Grease

Dairy Manure



Source: Milbrandt, A., Seiple, T., Heimiller, D., Skaggs, R., Coleman, A. "Wet waste-to-energy resources in the United States". *Resources, Conservation and Recycling.* Volume 137, October 2018, Pages 32-47.
Source: Seiple, T. et al. "Municipal wastewater sludge as a sustainable bioresource in the United States". *Journal of Environmental Management.* Volume 197, July 2017, Pages 673-680.

How does methane form?

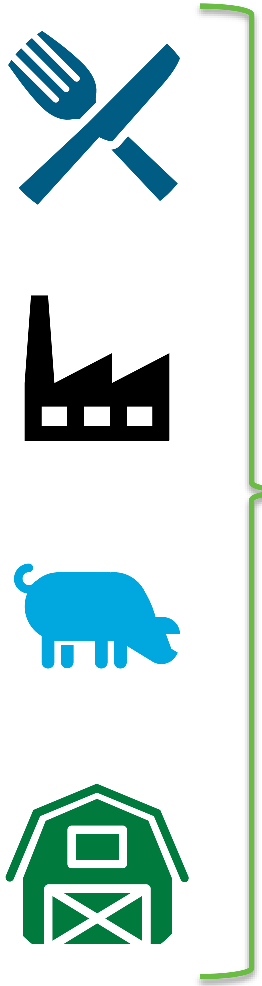
Anaerobic digestion is the process by which organic material decomposes into smaller molecules, and eventually, methane.

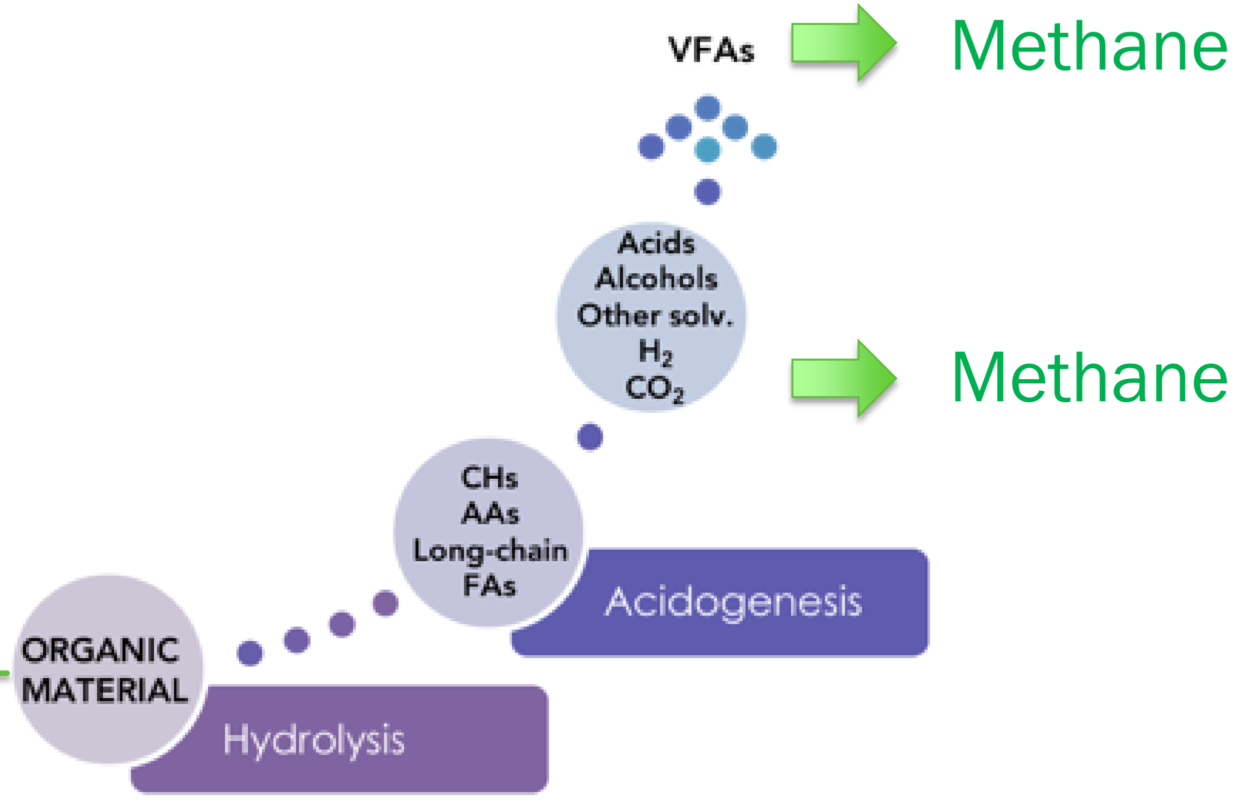
Naturally occurring microbes, known as methanogens convert organic matter and carbon dioxide into methane.

Anaerobic digestion is a natural process! It happens in landfills, in mines, farms, sewers…

and even inside cows!!!

Organic Waste

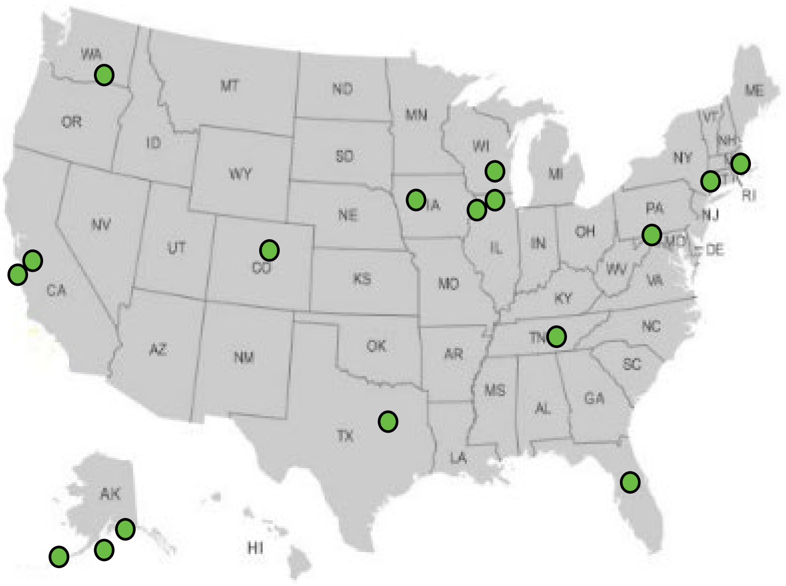




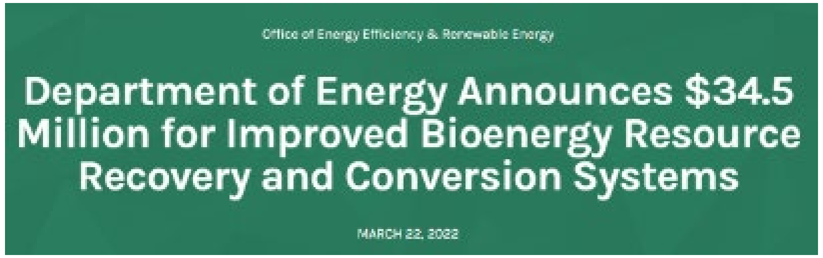
AA = amino acids | CH = carbohydrates | FA = fatty acids | H2 = hydrogen | VFA = volatile fatty acid

How can we prevent methane? What is BETO doing about it?

1. **Diverting organic waste from landfills**
   – Helping communities evaluate options other than landfilling
   – Funding feasibility development for communities
2. **Improving affordability of engineered digester systems**
   – Next generation anaerobic digester technology for small-scale systems/communities
   – Improving the economics of gas upgrading and utilization
3. **Develop technologies that prevent formation of methane altogether**



NREL and BETO technical assistance recipients in 2021



NEW FUNDING OPPORTUNITY HELPS UNDERSERVED COMMUNITIES TURN WASTE INTO A RESOURCE FOR A CLEAN AND EQUITABLE ENERGY ECONOMY

How can we prevent methane? What is BETO doing about it?!

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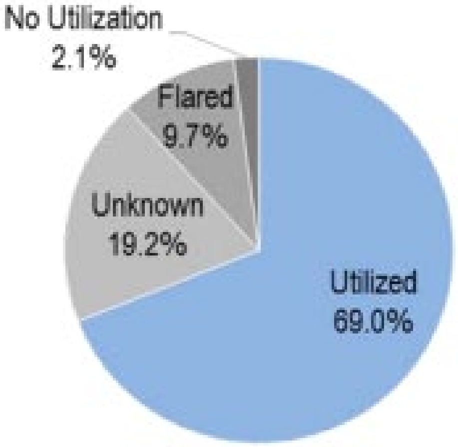
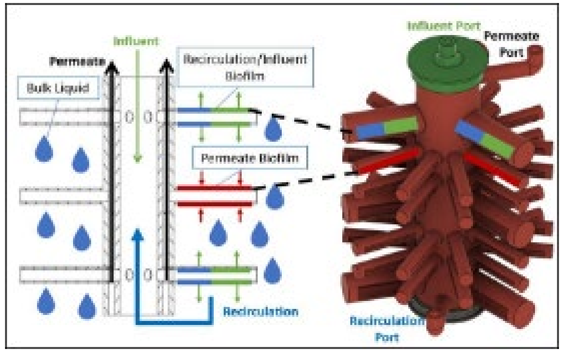
700 L / 250 kW system at the National Renewable Energy Laboratory Operational as of August 2019

Summit Natural Gas MAINE
NREL National Renewable Energy Laboratory
SoCalGas A Sempra Energy utility
Electrochaea
Lawrence Livermore National Laboratory
Stanford University



Biogas Utilization at US WWTs
Source: Shen et al. 2015



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Argonne National Laboratory

How can we prevent methane? What is BETO doing about it?

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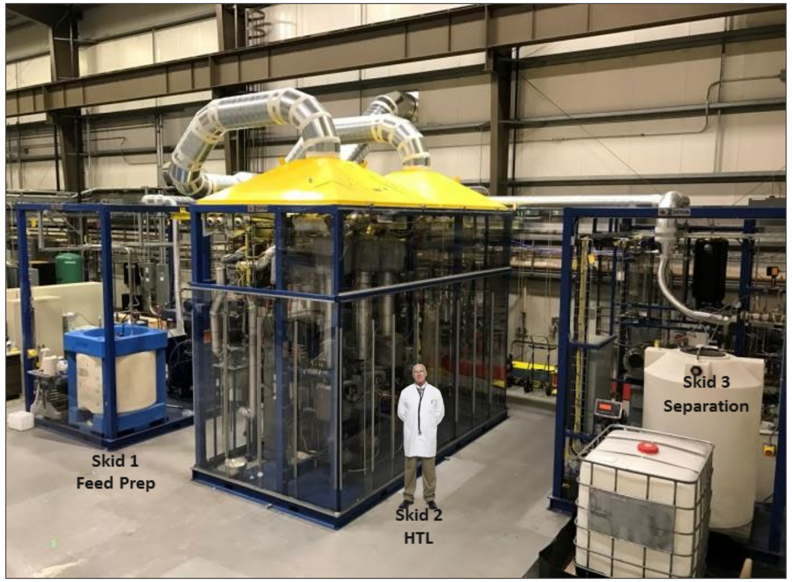

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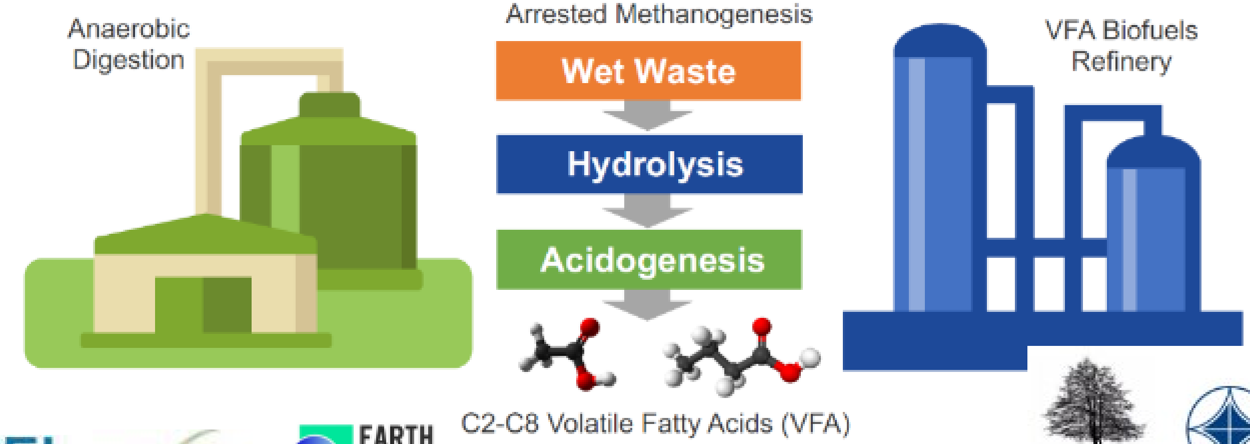

NREL
world energy
Earth Energy Renewables
Alder Fuels
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U.S. Department of Energy’s Strategy on Organic Waste

- **Significant congressional interest in solving these problems over the years:**
  - Renewable Natural Gas
  - Community Digesters/Solutions
  - International Collaborations
  - Innovative use of Biosolids

- **BETO has developed a multi-pronged strategy to:**
  1) Manage these economic, environmental, and social liabilities
  2) Convert these liabilities into revenue streams
  3) Support community development and ownership of these projects

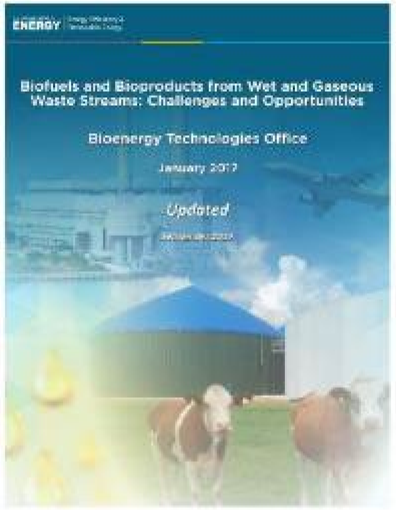
BETO’s Activities on Organic Waste (2019–2022):
5 Funding Opportunity Announcement Topics

~$50M in funding:

- >$22M on liquid fuels from waste
- >$12M on products/chemicals from waste
- >$16M on Renewable Natural Gas or small scale digester systems

In addition:

- ~$1M/yr on techno-economic and life cycle analyses
- ~$1.5M/yr on experimental R&D



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Increase in atmospheric methane set another record during 2021

Carbon dioxide levels also record a big jump

> "Control of many methane sources technically possible today"

Happy Earth Day!

Please Reach Out!

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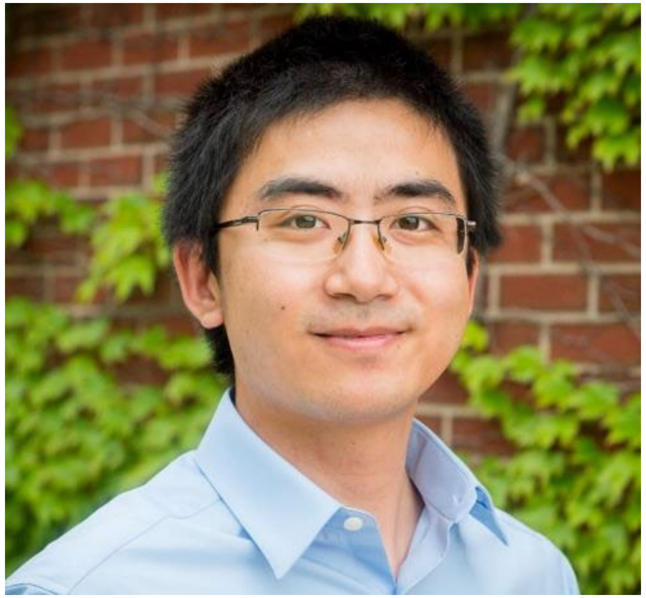


Dr. Hao Cai

Principal Environmental Analyst

Argonne National Laboratory

APRIL 20, 2022

Reducing Methane Emissions Via Waste-To-Energy Technologies

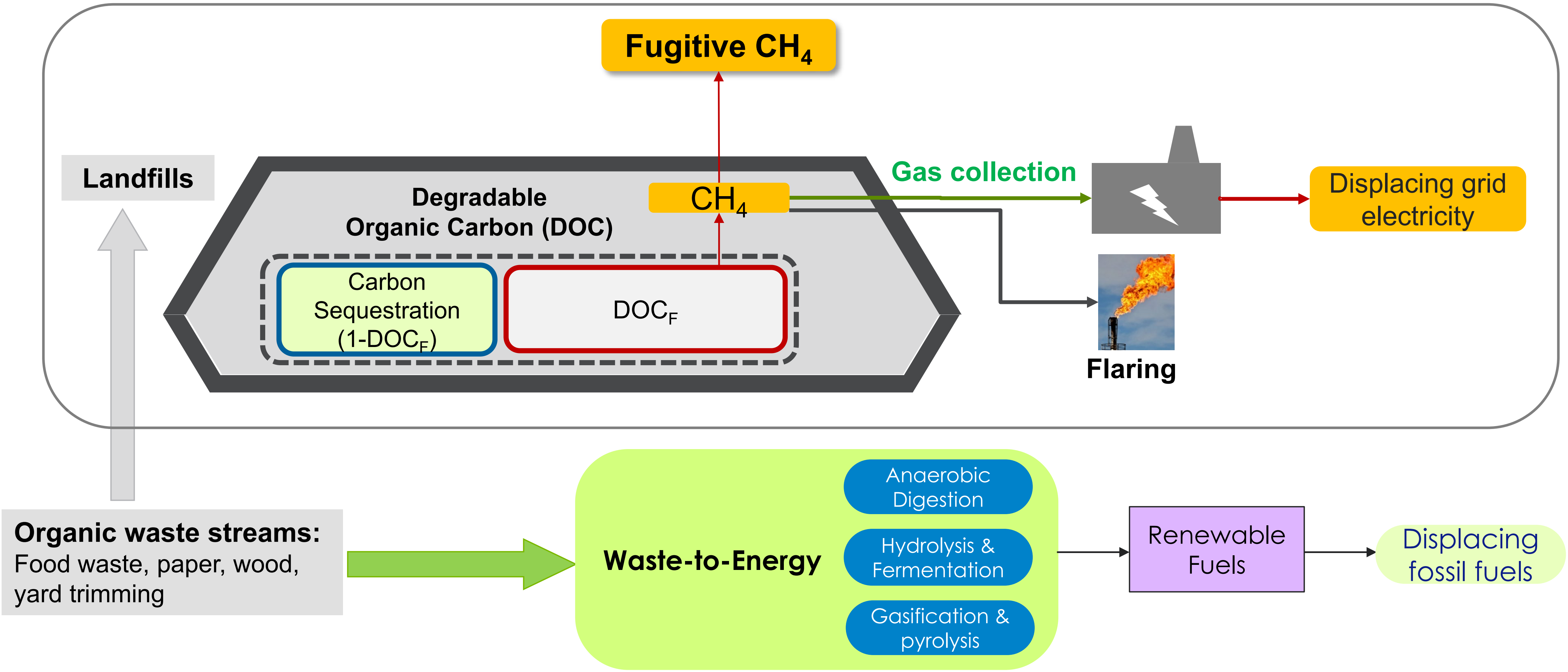
Hao Cai

Principal Environmental Analyst

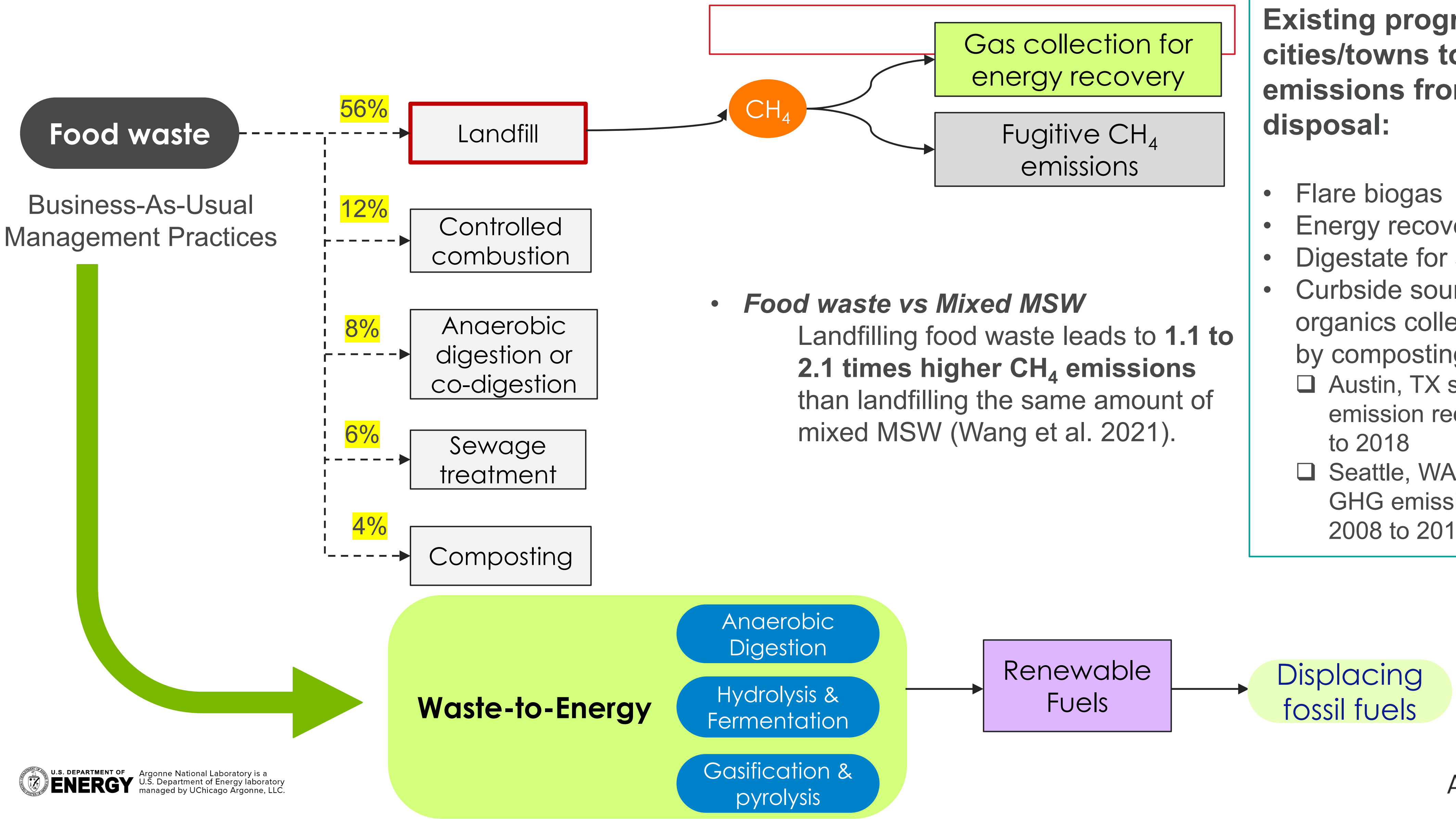
Systems Assessment Center

Argonne National Laboratory

Landfills: CH_4 emissions and mitigation approaches



Food Waste: Current management practices and mitigation approaches



- ***Food waste vs Mixed MSW***
  Landfilling food waste leads to **1.1 to 2.1 times higher CH_4 emissions** than landfilling the same amount of mixed MSW (Wang et al. 2021).

Existing programs in cities/towns to mitigate CH_4 emissions from food waste disposal:

- Flare biogas
- Energy recovery
- Digestate for soil amendment
- Curbside source-separated organics collection, followed by composting
  - ❑ Austin, TX saw 17.5% GHG emission reduction from 2013 to 2018
  - ❑ Seattle, WA observed 25% GHG emission reduction from 2008 to 2018

Animal Manure: Current management practices and mitigation approaches

BAU

Animal manure

Dairy cow manure 51%
- Anaerobic lagoon, liquid/slurry, solid storage
- Daily spread.

Swine manure 37%
- Deep pit
- Anaerobic lagoon, liquid/slurry, etc.

Cattle manure 5%
- Dry lot, etc.

Controllable CH_4 emissions from:
- Anaerobic lagoon, solid storage, liquid/slurry storage, and dry lot.

Hard-to-collect CH_4 emissions from:
- Deep pit;
- Open application to land.

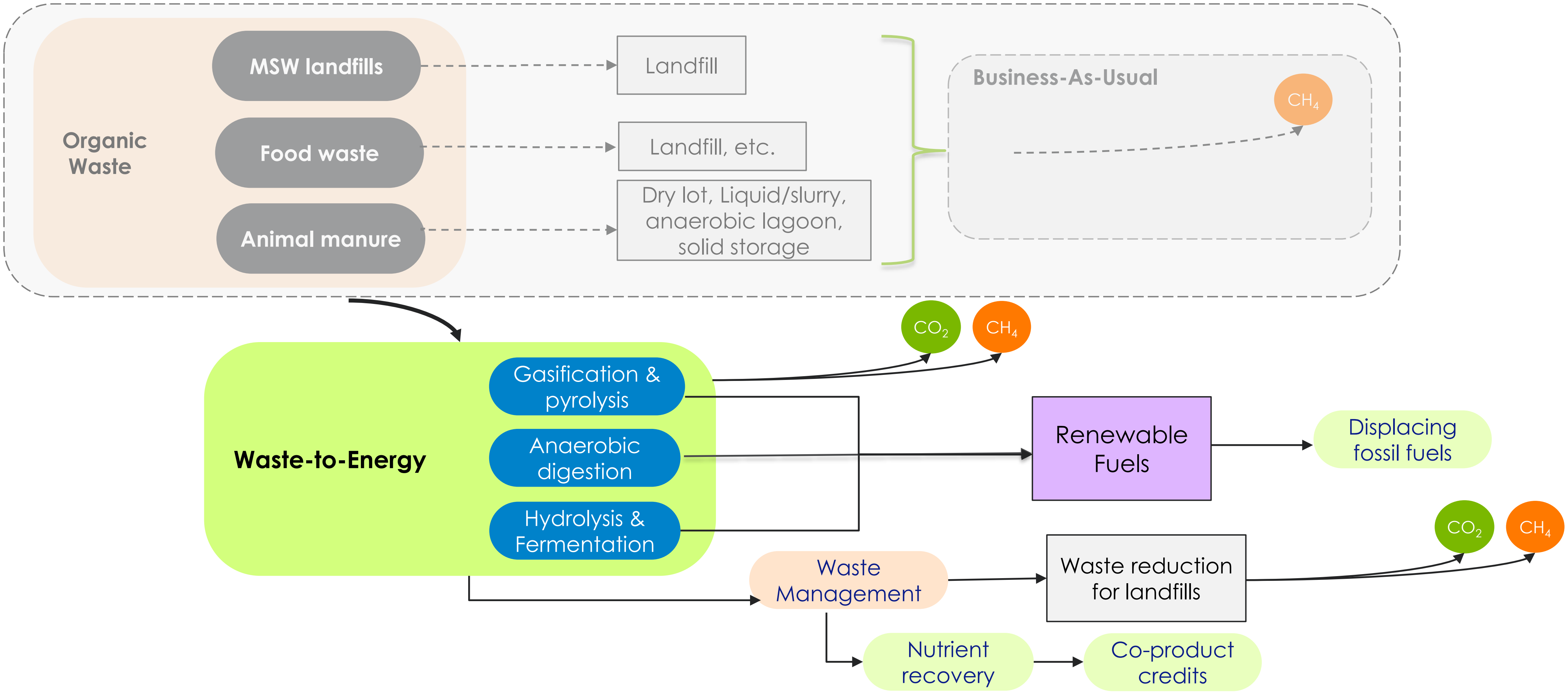
Existing programs in cities/towns to mitigate CH_4 emissions

- Flare biogas
- Energy and nutrient recovery
- On-farm digestors expanded to accept food waste (e.g., Mifflintown, PA)
  - ❑ increase biogas yield
  - ❑ renewable electricity for onsite use
  - ❑ sell excess to the grid

Waste-to-Energy
- Anaerobic Digestion
- Hydrolysis & Fermentation
- Gasification & pyrolysis

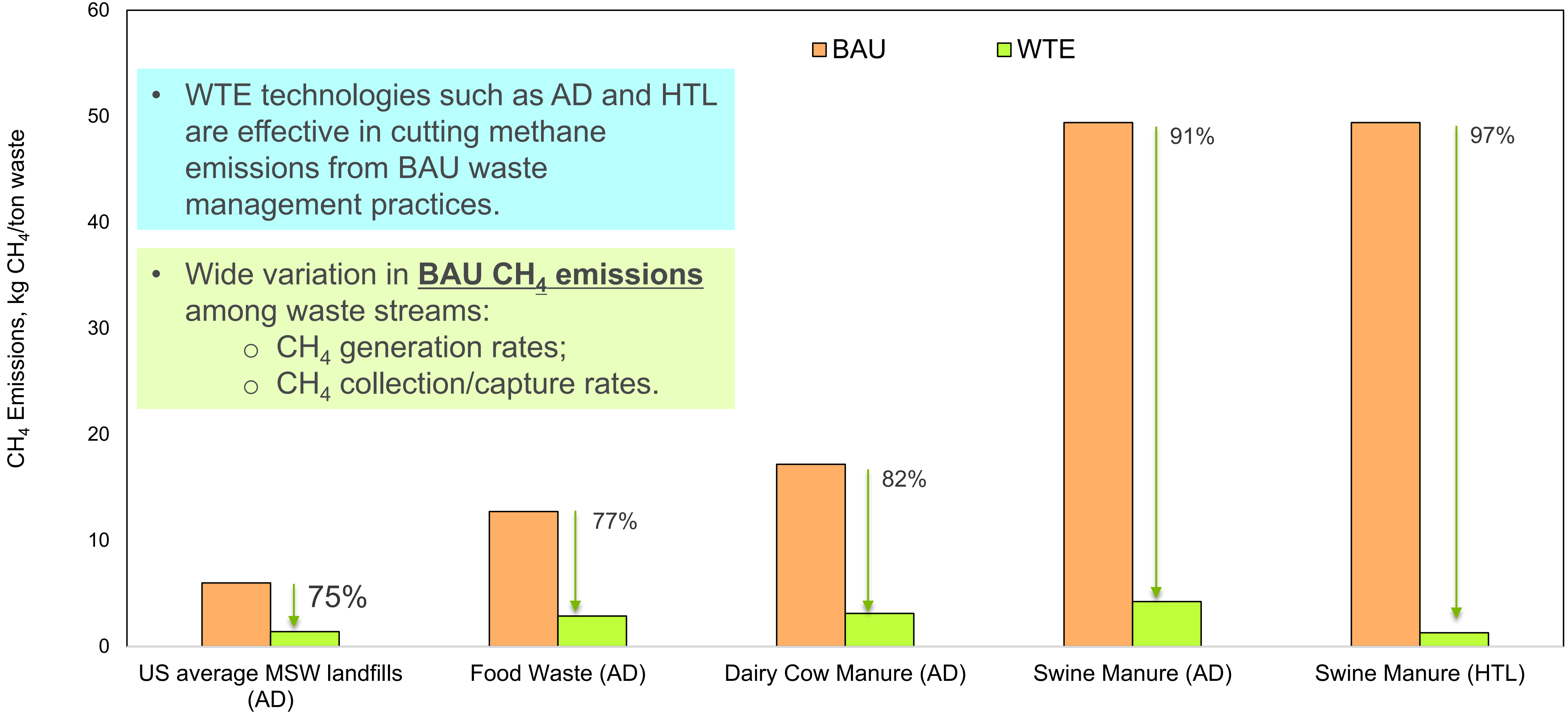
Renewable Fuels → Displacing fossil fuels

Diverting Waste Streams from BAU Management to WTE



Seq. CO_2: Avoided CO_2 emissions from sequestered carbon; AD: Anaerobic digestion;

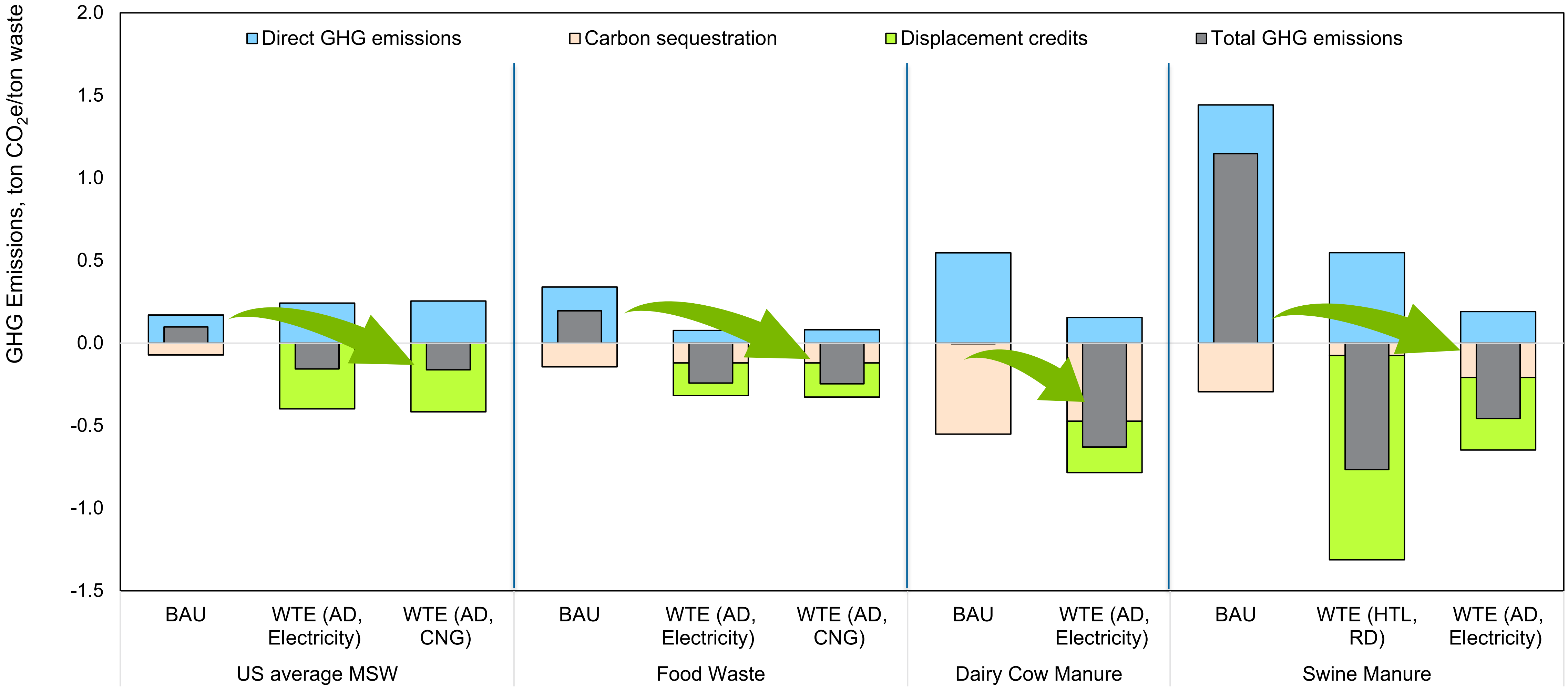
Potentials of WTE to Reduce Methane Emissions



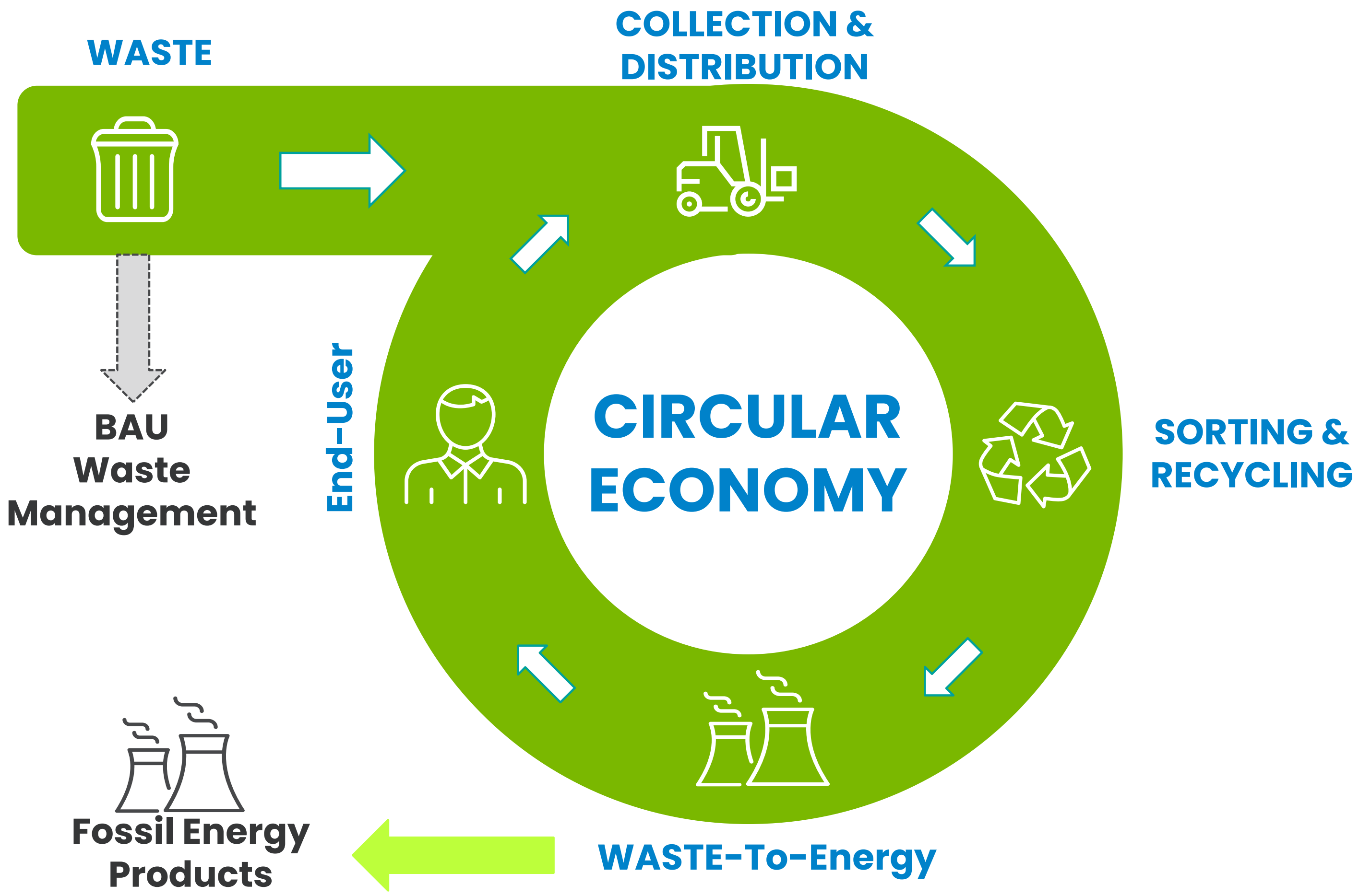
- WTE technologies such as AD and HTL are effective in cutting methane emissions from BAU waste management practices.

- Wide variation in **BAU CH_4 emissions** among waste streams:
    - CH_4 generation rates;
    - CH_4 collection/capture rates.

WASTE-To-Energy Generates Renewable Energy That Decarbonizes the Energy Sector



Waste-to-Energy Technologies Present Tremendous Opportunities to Promote Circular Economy and Significantly Reduce Methane Emissions from Organic Waste



This is methane's moment,

This is action time for communities,

Waste-to-Energy Technologies can play a BIG role.

Thank You!

Hao Cai, hcai@anl.gov

Argonne NATIONAL LABORATORY

Anelia Milbrandt

Senior Research Analyst

National Renewable Energy Laboratory

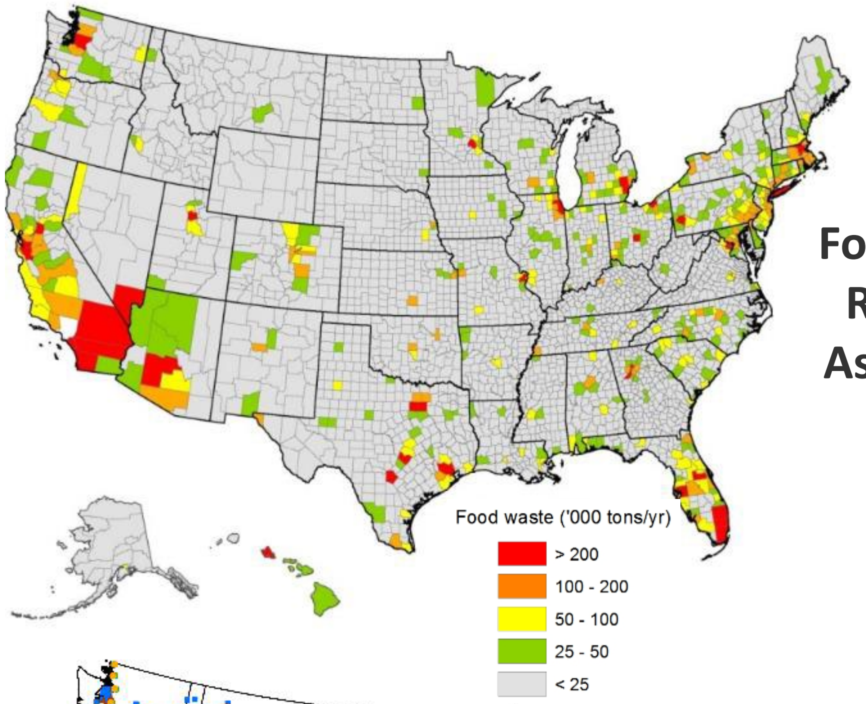
NREL
Transforming ENERGY

Opportunities to Reduce Methane Emissions for Communities

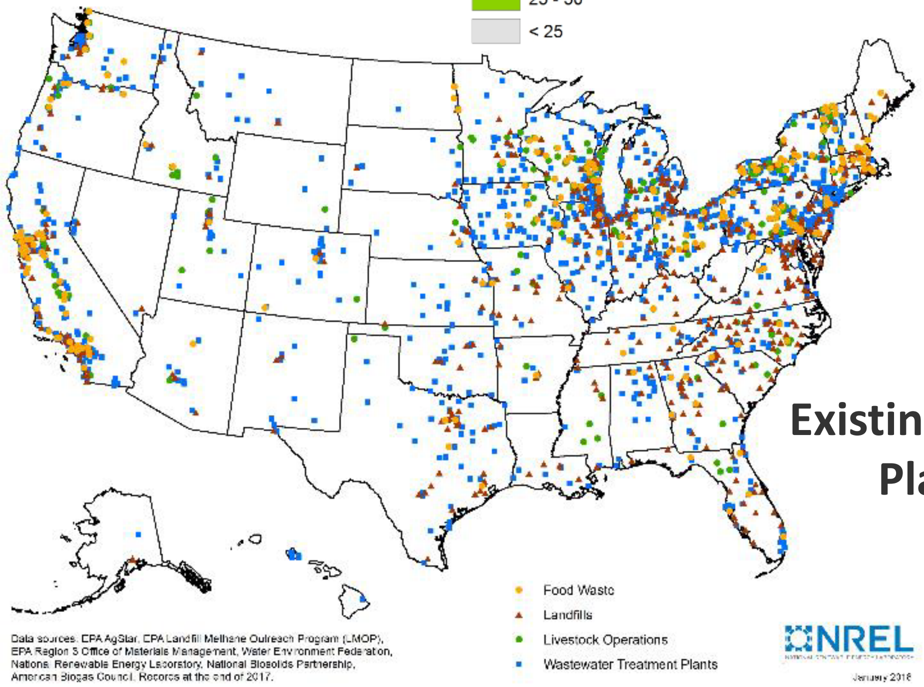
Anelia Milbrandt
BETO's Earth Day Celebration Webinar
April 20th, 2022

Organic Waste Research

- Resource assessment (quantity, geographic distribution, current use, etc.)
- Economic analysis of organic waste (prices, supply curves)
- Techno-economic analysis (e.g., key cost drivers, technical challenges, targets for a process)
- Cost-benefit analysis (e.g., food waste disposal and utilization pathways)
- Market and policy analyses (existing and potential markets, available credits, regulations for disposal and handling, etc.)
- Socio-economic evaluation (e.g., jobs, economic development)



Food Waste Resource Assessment



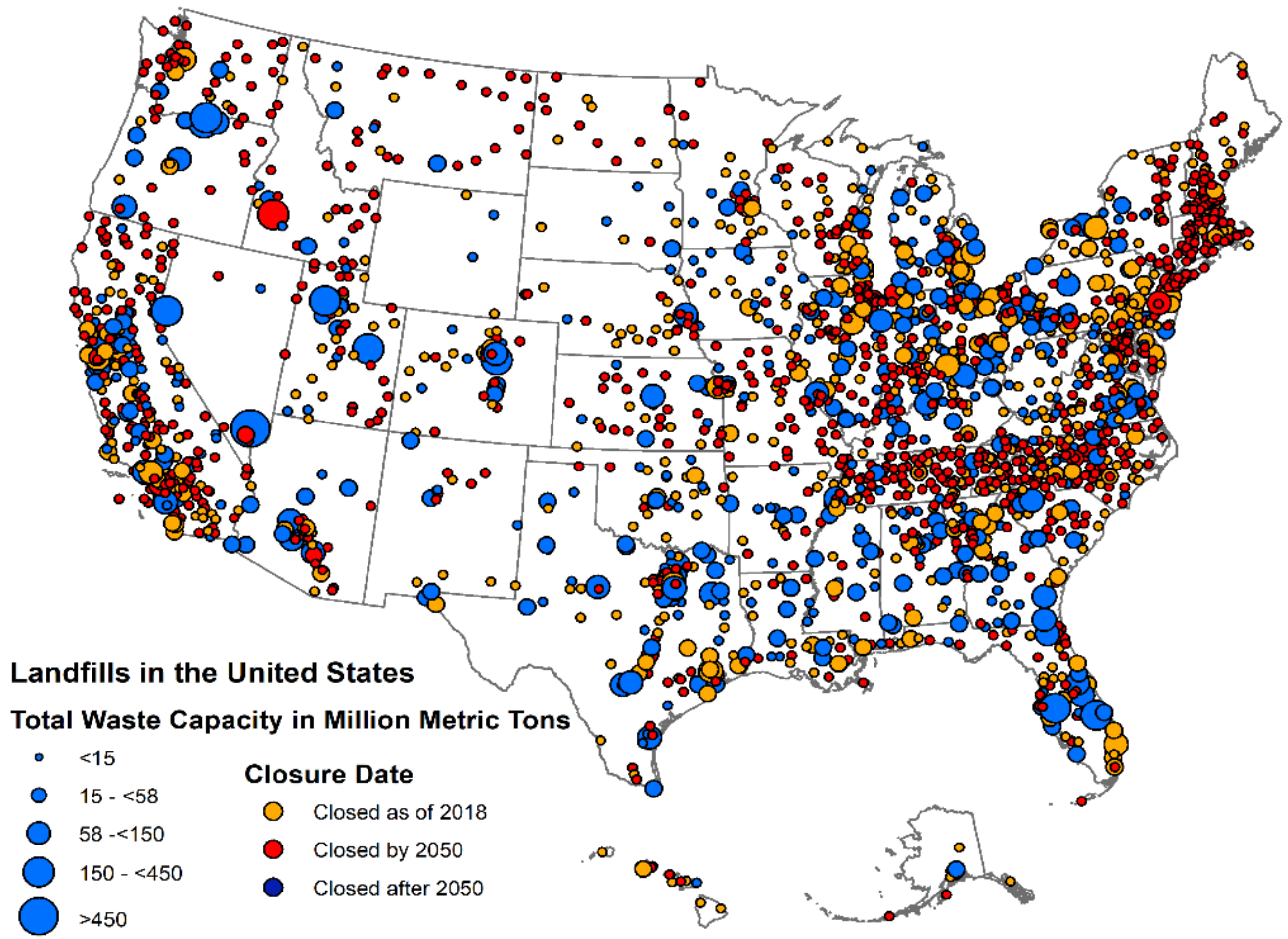
Existing Biogas Plants

Work with Communities

- Waste-to-Energy Technical Assistance (WTE TA) launched during FY 2021
- The goal of the WTE TA is to mobilize data and information compiled about organic waste streams and:
  - Provide this data to local decision makers
  - Deploy the analyses that have been developed for a variety of energy/resource recovery strategies
  - Foster local public-private partnerships
- 17 communities participated in FY 2021
- FY 2022 applications received during March 2022

Drivers of Change in Communities

- Challenges associated with:
  - Landfills closing soon
  - Land constraints
  - Energy/environmental justice issues
- Communities motivated by sustainability objectives



Relevant Goals and Plans

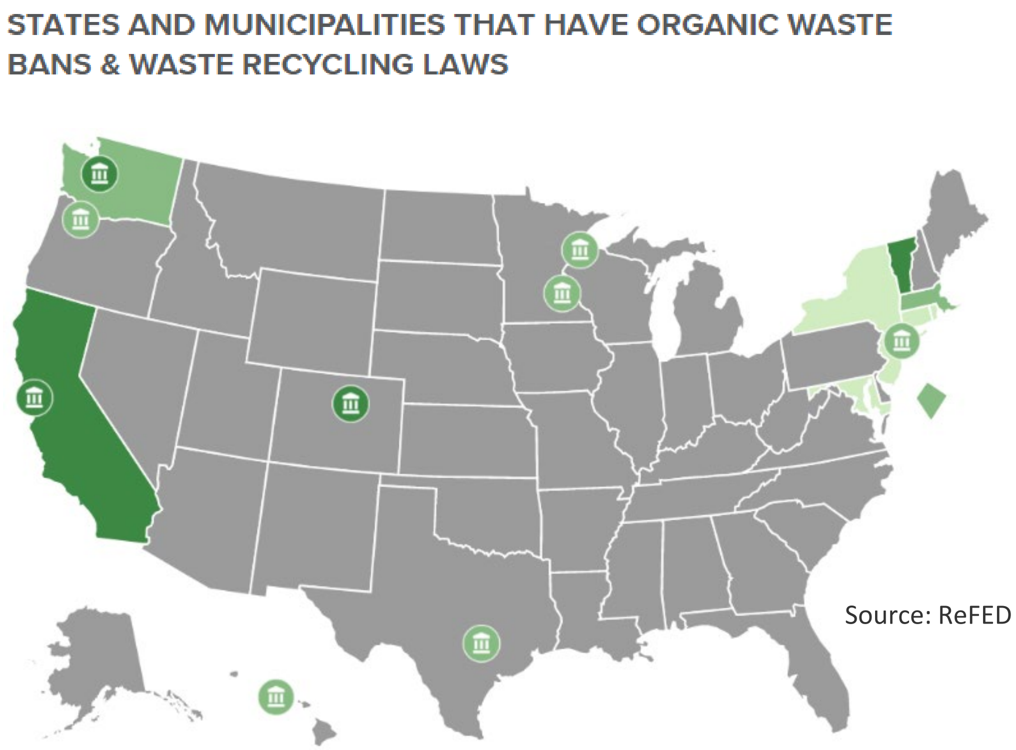
- Divert a substantial amount of waste from landfills (e.g., 50%, 75%)
- Zero waste
- Circular Economy Program
- Climate Action Plan
- Sustainability Plan

Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), Germany; ooyoo/gettyimages.

Reducing GHG emissions may not be the goal for a community but by reducing the amount of waste going into landfills or using the waste in beneficial ways provide the benefit of GHG emissions reduction.

Communities' Actions

- Legislature (e.g., organic waste bans)
- Automatically include organics collection service as part of the waste collection program
- Pay-As-You-Throw Program
- Zero Waste Event Rebate
- Technology implementation (e.g., anaerobic digestion, composting, landfill gas capture, etc.)



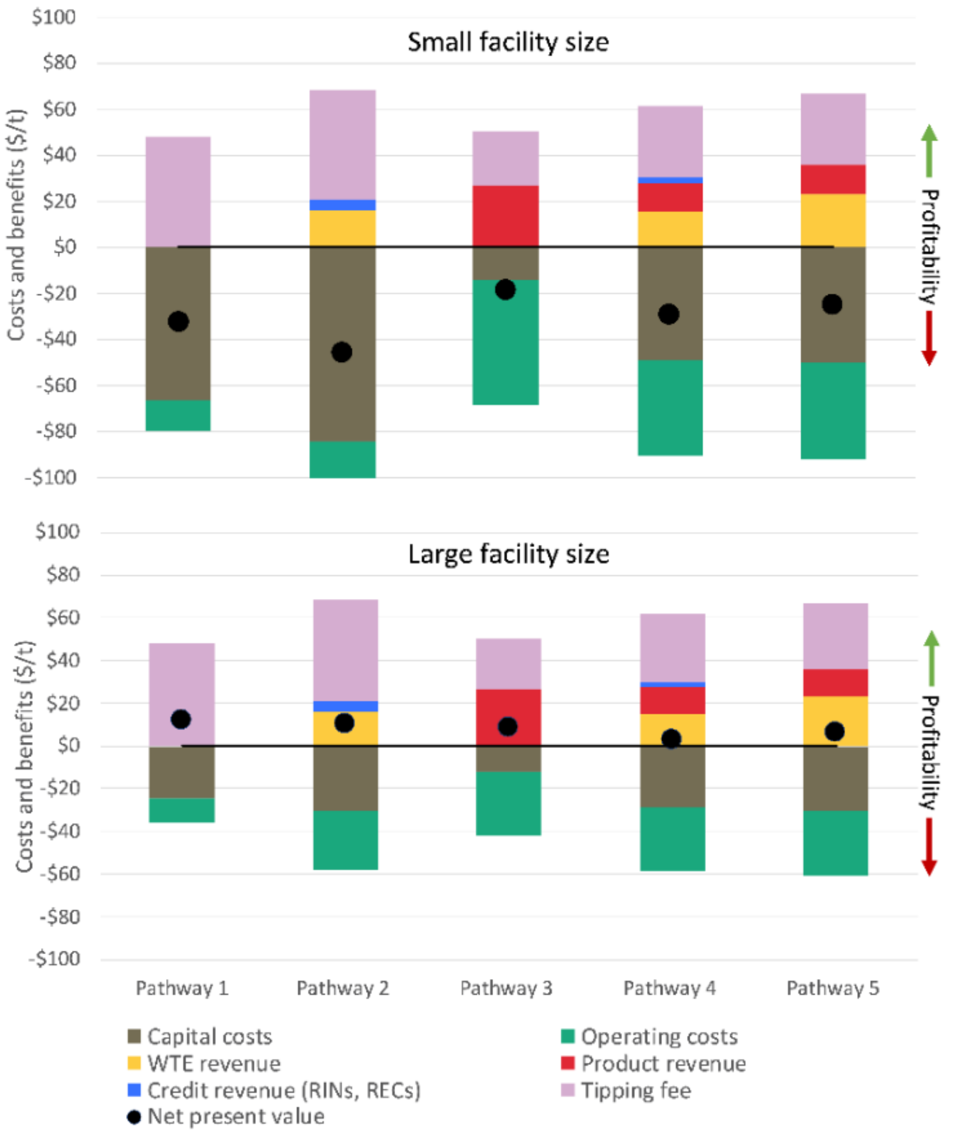
Source: ReFED

Picture taken by Anelia Milbrandt, Denver Zoo

How We Have Helped Communities?

- Anaerobic digestion (AD) of organic waste captures methane and allows for its use in a beneficial way
- The *Global Methane Assessment* published by the UN Environment Programme and Climate and Clean Air Coalition in May 2021 notes AD as "one of the key technologies that can deliver methane reductions at low cost"
- We help communities understand the costs and benefits associated with various AD pathways (flare, electricity, CHP, CNG, and pipeline injection) to make informed decisions.

Cost-Benefit Analysis of Food Waste Disposal and Utilization Pathways



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Newtrient LLC
North Carolina State University
U.S. Department of Agriculture–Natural Resource Conservation Service
U.S. Environmental Protection Agency Landfill Methane Outreach Program

Photo from iStock-627281636

Jason Feldman

Co-Founder

Green Era Sustainability

This speaker requested that the presentation slides from Green Era Sustainability be removed from the final posted presentation.

Thank you!

Today's Presentation:

Promising Approaches for Reducing Methane Emissions in the United States

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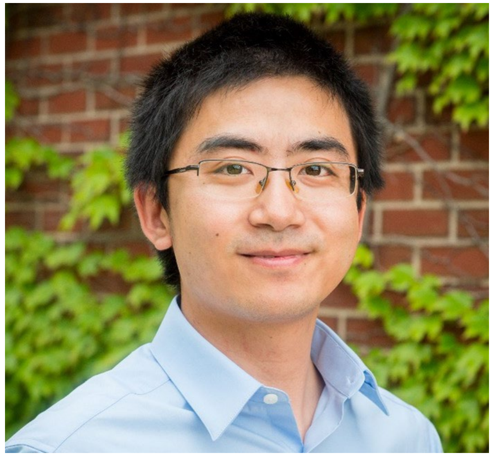

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