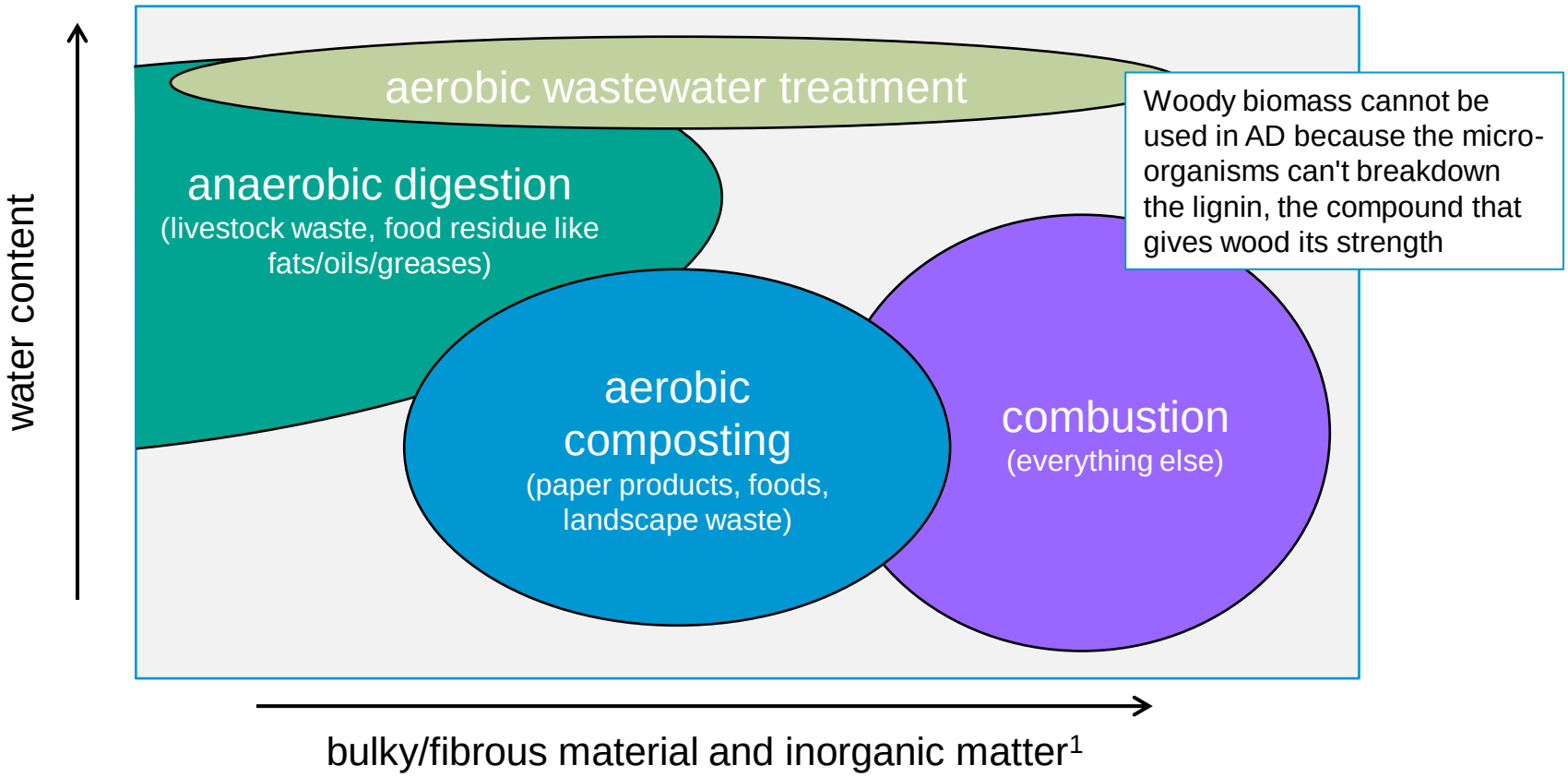
Perspective:

Bioplastics & Anearobic Digestion

Perspective: Bioplastics & AD

- AD – overview of the landscape
- AD – the basics
- AD – system types & how bioplastics integrate
- Ingeo PLA in AD

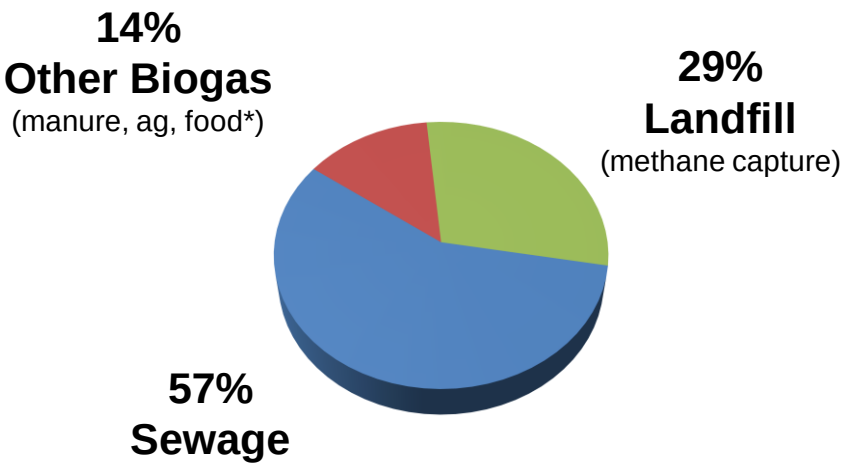
Different waste treatment technologies require specific feedstock characteristics



how anaerobic digestion stacks up in the waste treatment world

A context on Biogas Sites & Biomass Sources by Region

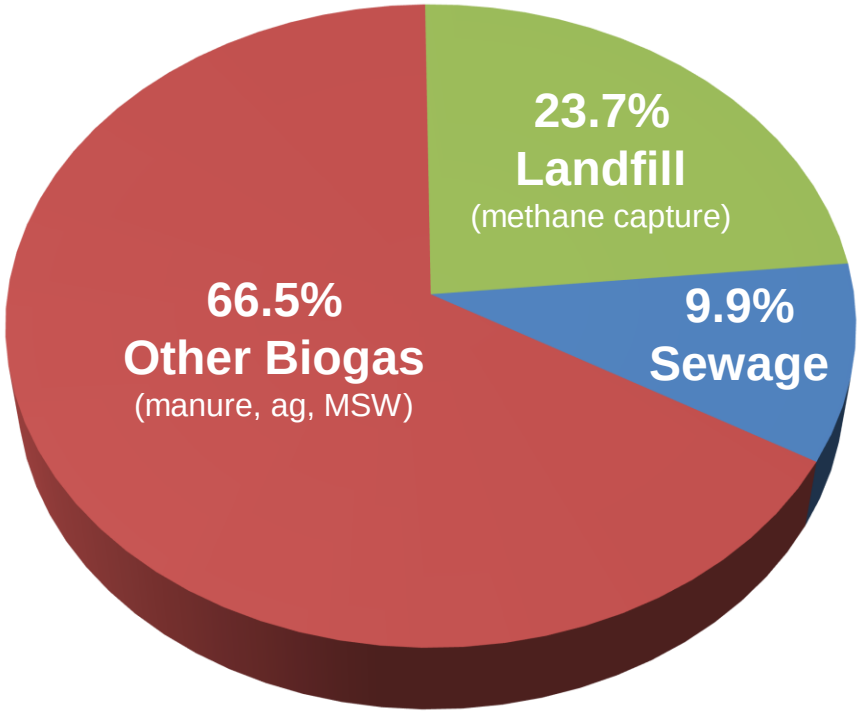
USA[2]



Total biogas sites: 2,170

**of these ~20 sites accept food waste[3]*

EUROPE[4]



Total biogas sites: 13,800[5]

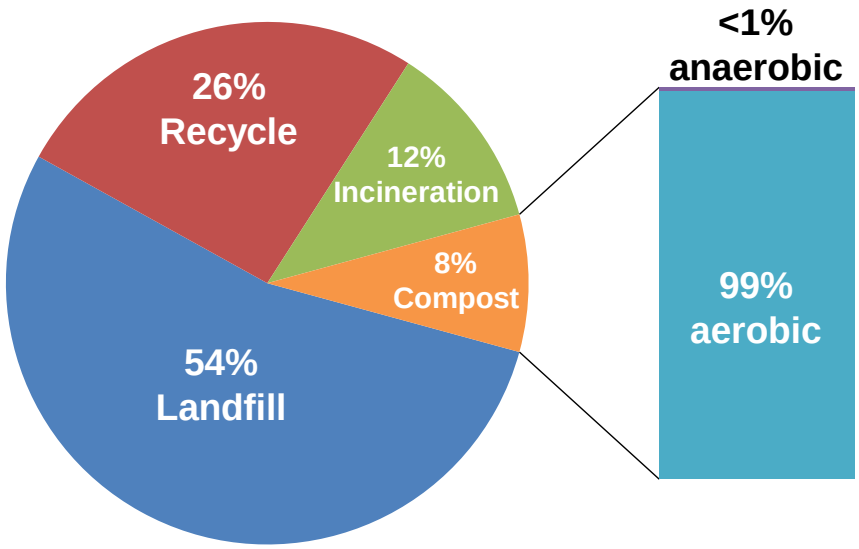
**of these ~195 sites accept MSW incl. food waste[6]*

US Biogas Market is <1/6th the size of Europe, and accepts much more food waste

Digging into to that MSW

~20 AD plants accept food waste or MSW in the US compared to ~195 in Europe

USA[7]

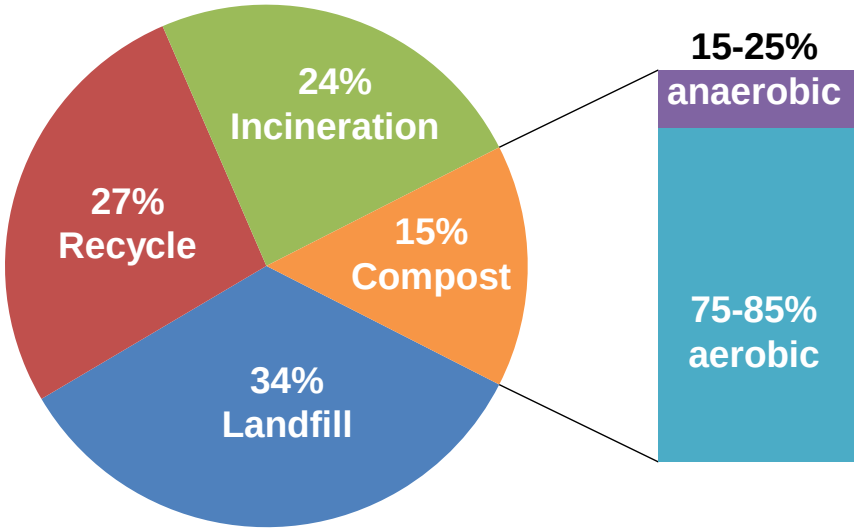


Total MSW in 2010: 250.4 million MT

Population: 313.9 million

2.16 kg / person / day

EUROPE[8]



Total MSW in 2010: 219.6 million MT

Population: 505.7 million

1.35 kg / person / day

More waste is generated in the US per capita than Europe & yet landfill is still the primary disposal option

AD sites in North America that accept food waste

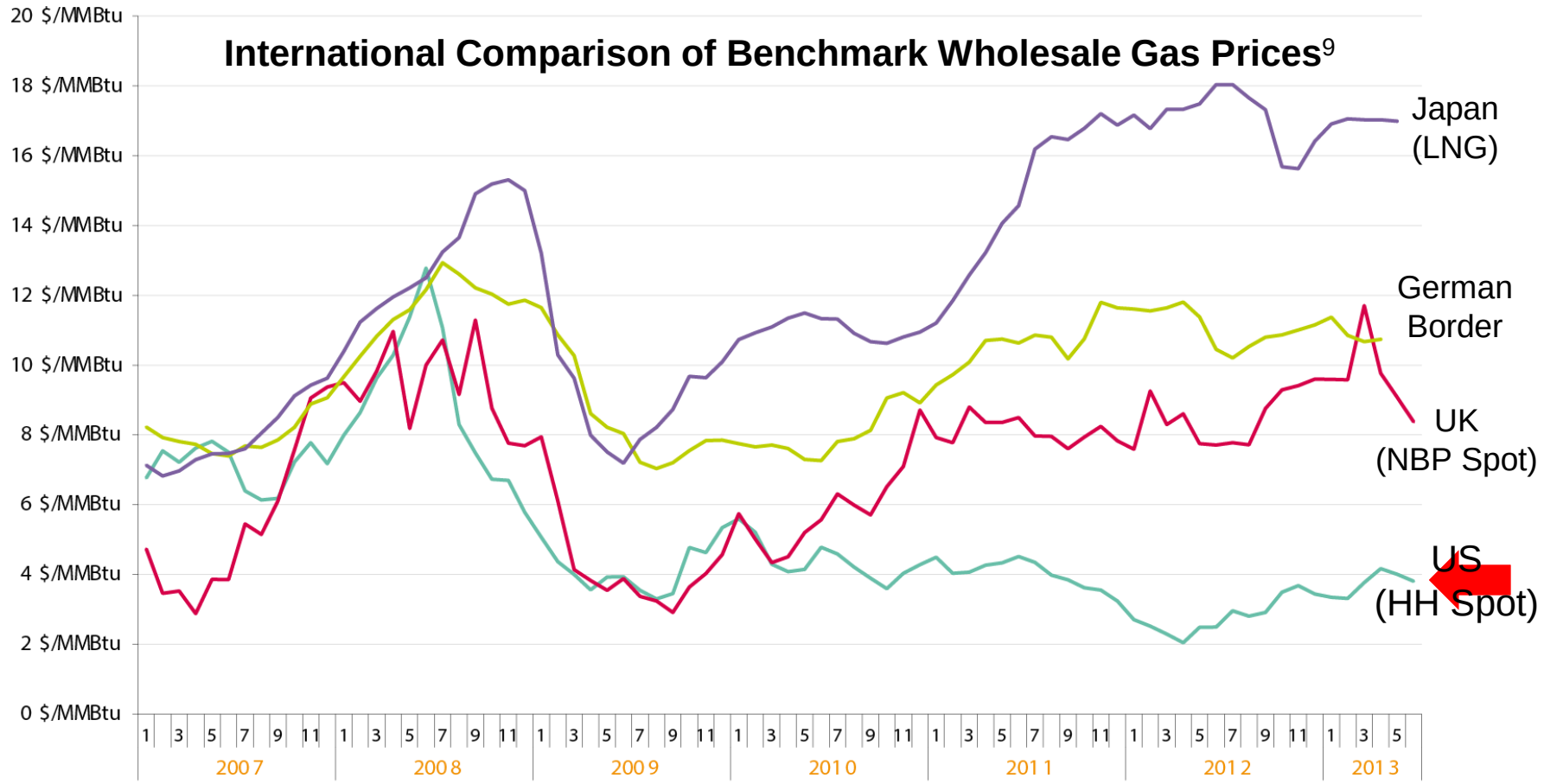
Dufferin Organics Facility*	Toronto, CA
East Bay Municipal Utility District	Oakland, CA
Gills Onions	Oxnard, CA
Newmarket Organic Processing Facility	Newmarket, ON
UC-Davis Pilot Plant	Davis, CA
University of Wisconsin – Oshkosh*	Oshkosh, WI
West Lafayette/Purdue	West Lafayette, IN
Millbrae	Millbrae, CA
Old Dutch Potato Chip Co.	Roseville, MN
Huckabay Ridge	Stephenville, TX
Stargest Power LLC	Elk Mound, WI
Norswiss Digester LLC	Rice Lake, WI
Buckeye Ridge Renewable Power LLC	La Farge, WI
Santa Monica WWTF*	Santa Monica, CA
Harvest Power*	Vancouver, BC
JC Biomethane*	Junction City, OR
Harvest Energy Garden	Orlando, FL
Zero Waste Energy Development Company*	San Jose, CA
Merchant Digester	Columbus, OH

- Approximate list as more & more WWTP are co-digesting FOG or commercial organic waste to increase their biogas output
- 6 sites (*) accept curbside or residential food waste
- ¾ of these have received grants, tax credits & subsidies
- Most generated electricity/heat is used at the facility to reduce costs, not sold to the grid (= financial stability)
  - Some farms like Norswiss use AD primarily for the by-products like good bedding, which can increase milk production in cows
- Capital investments range: $5MM - >$30MM
- 12 private, 4 public, 3 public/private

Why is there more AD in Europe than in the US?

- **Legislation drives favorable economics**
  - European Waste Framework Directive
    - Member states shall take measures to encourage the separate bio-waste collection with a view to the composting and digestion of bio-waste
  - European Landfill Directive
    - Diversion of biodegradable waste from landfills (reduction to 35% of 1995 level by 2020)
  - European Renewable Energy Directive
    - 20% share of energy from renewable sources by 2020
    - Germany will go beyond 20% as they shutdown nuclear plants by 2022
- Similar legislation does not exist on a national level in the US
    - Closest example: U.S. govt is targeting 20% of the electricity consumed by Federal agencies from renewable energy by 2020
- Very low cost natural gas in the US - makes biogas less attractive

Comparing Wholesale Gas Prices



Gas prices in the US are very low, making biogas less economically attractive than EU

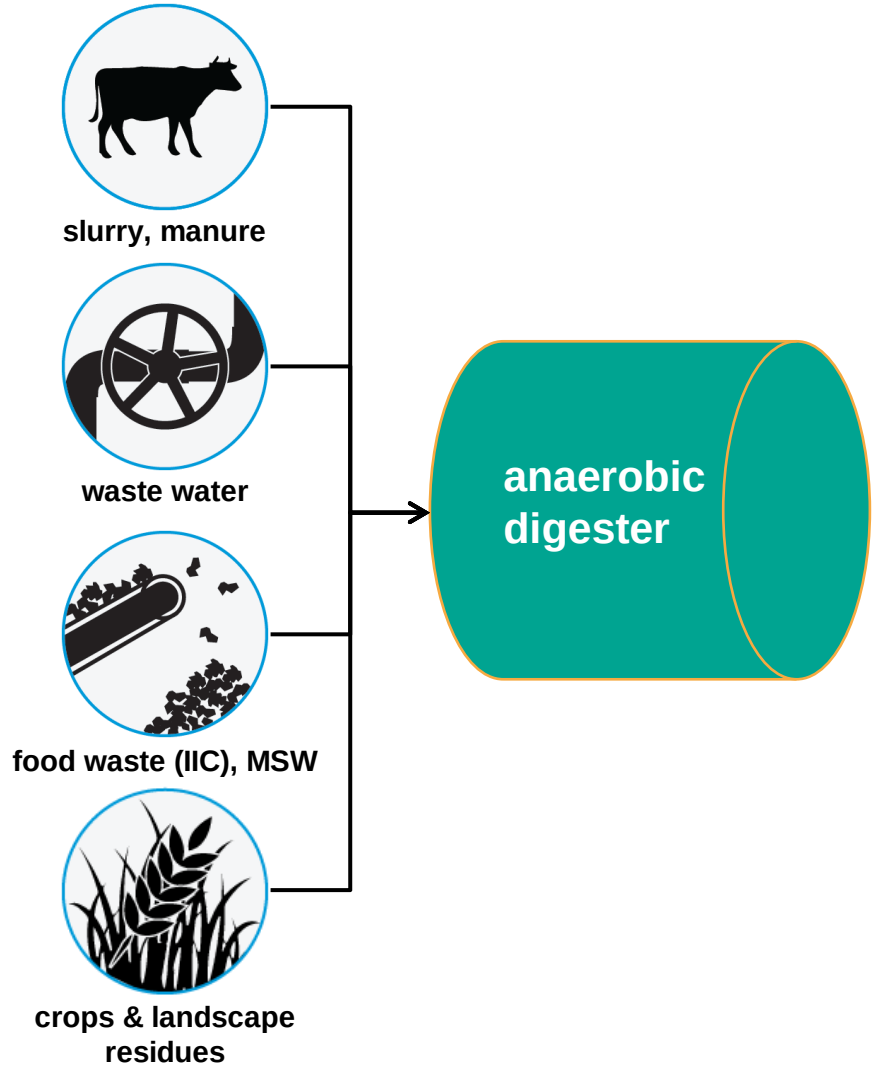
anaerobic digestion: the basics

an·aer·o·bic di·ges·tion | a-nə-ˈrō-bik dī-ˈjes-chən |

adjective·noun

1 a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen with a common end-product of biogas

anaerobic digestion: the basics



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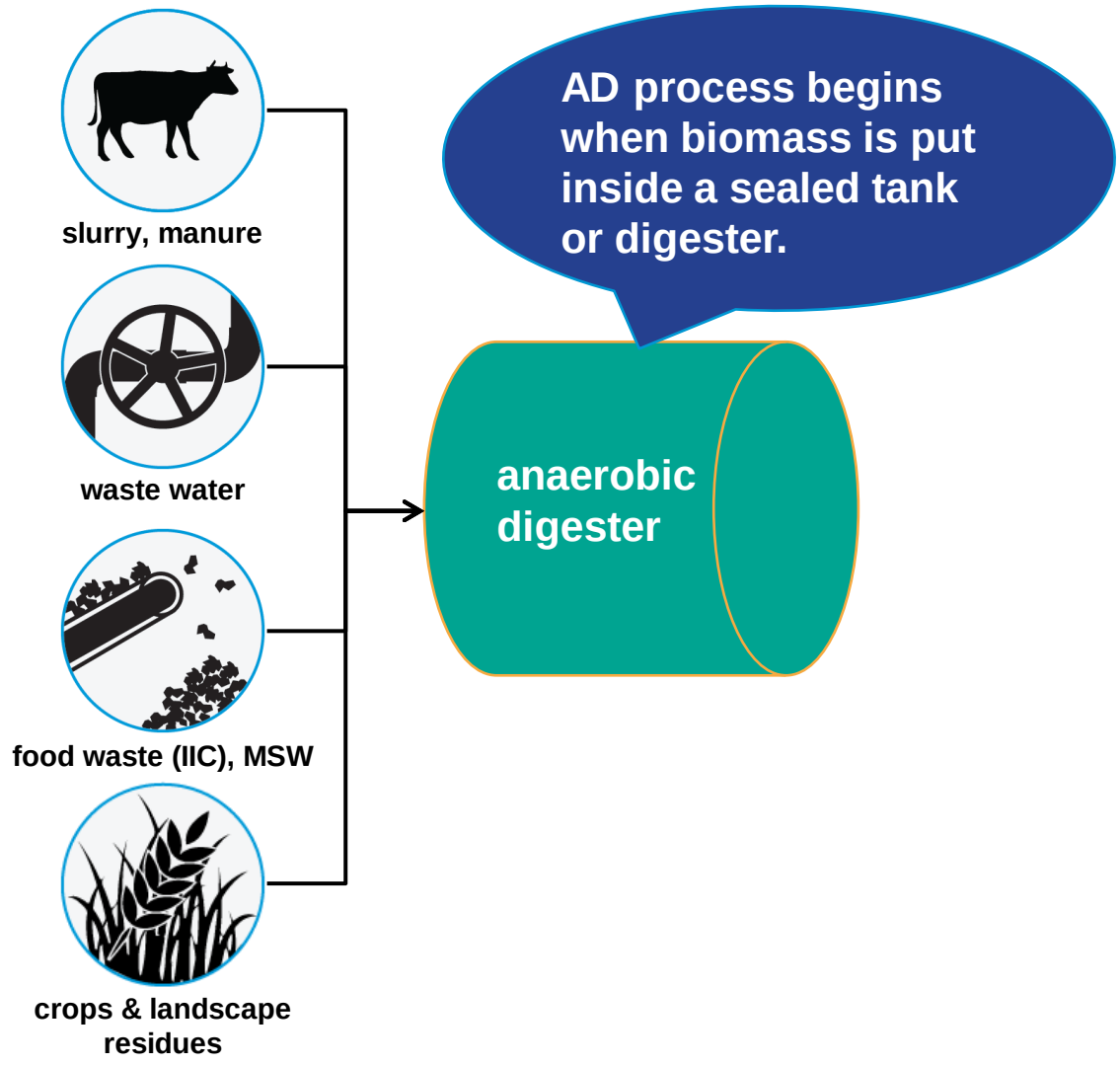

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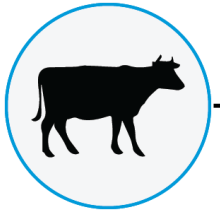


slurry, manure

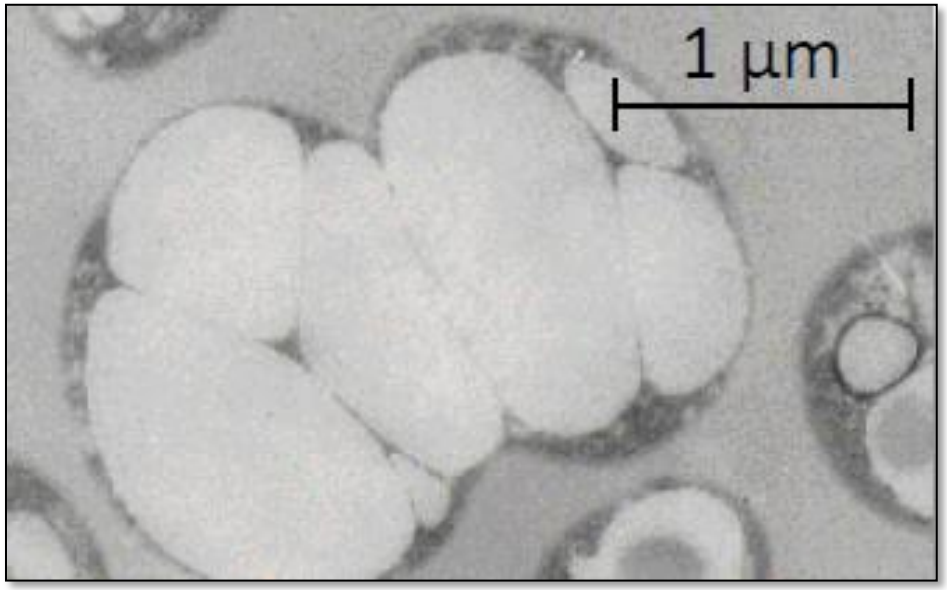
waste water

food waste (IIC), MSW

crops & landscape residues

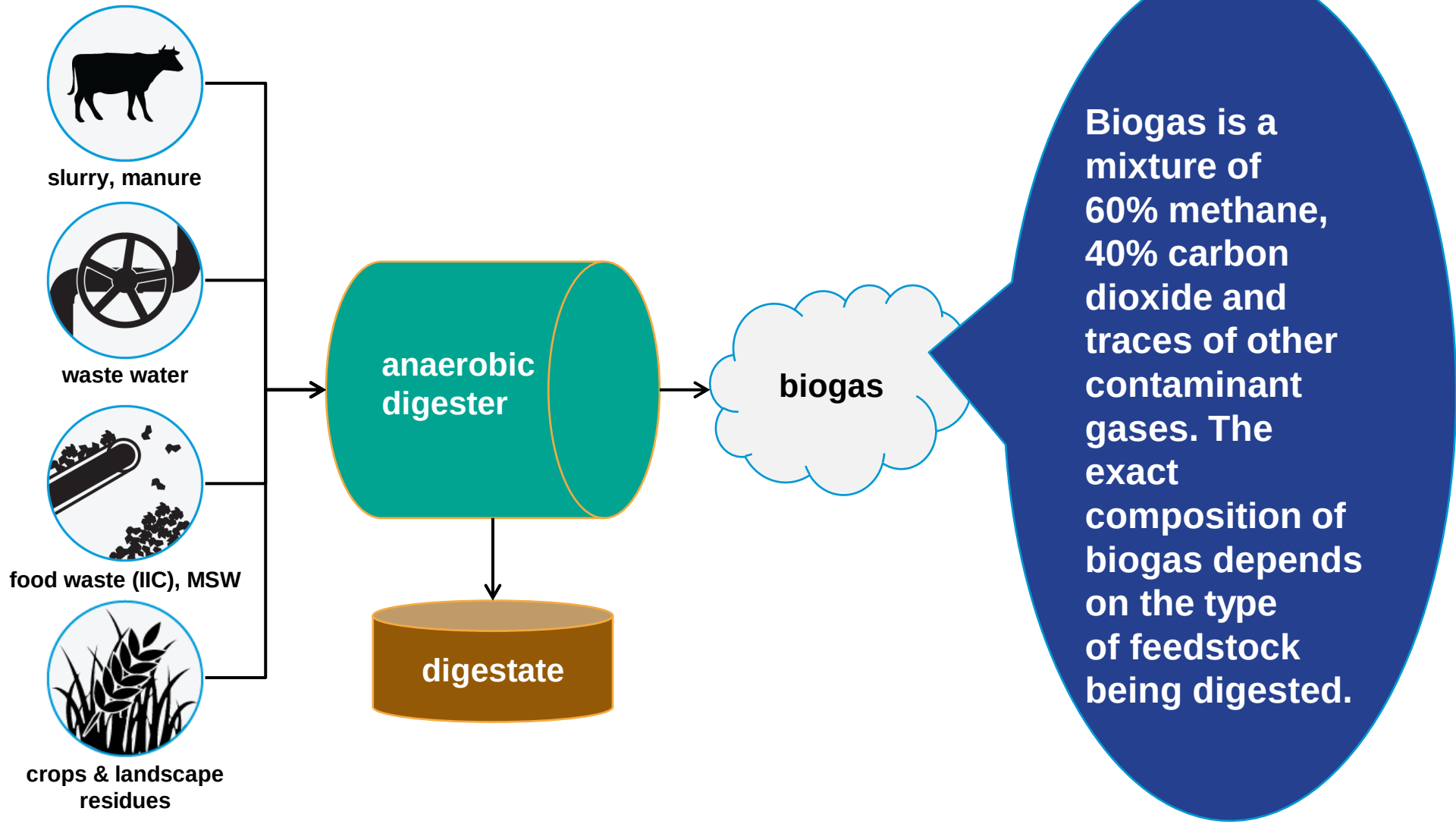
Naturally occurring micro-organisms digest the biomass, which releases a methane-rich gas (biogas) that can be used to generate renewable heat and power.

anaerobic digester

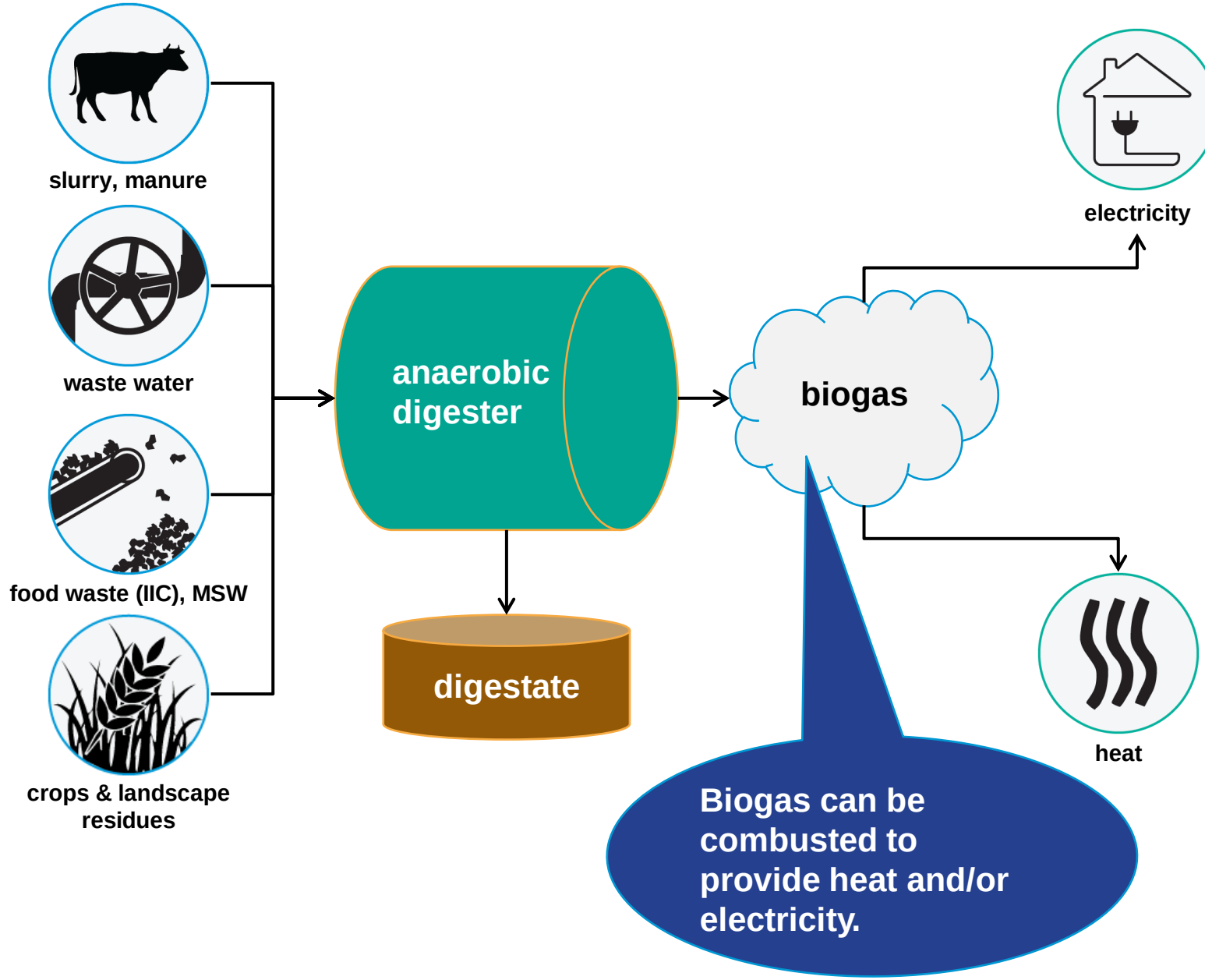


Time of operation per cycle is typically 15-30 days

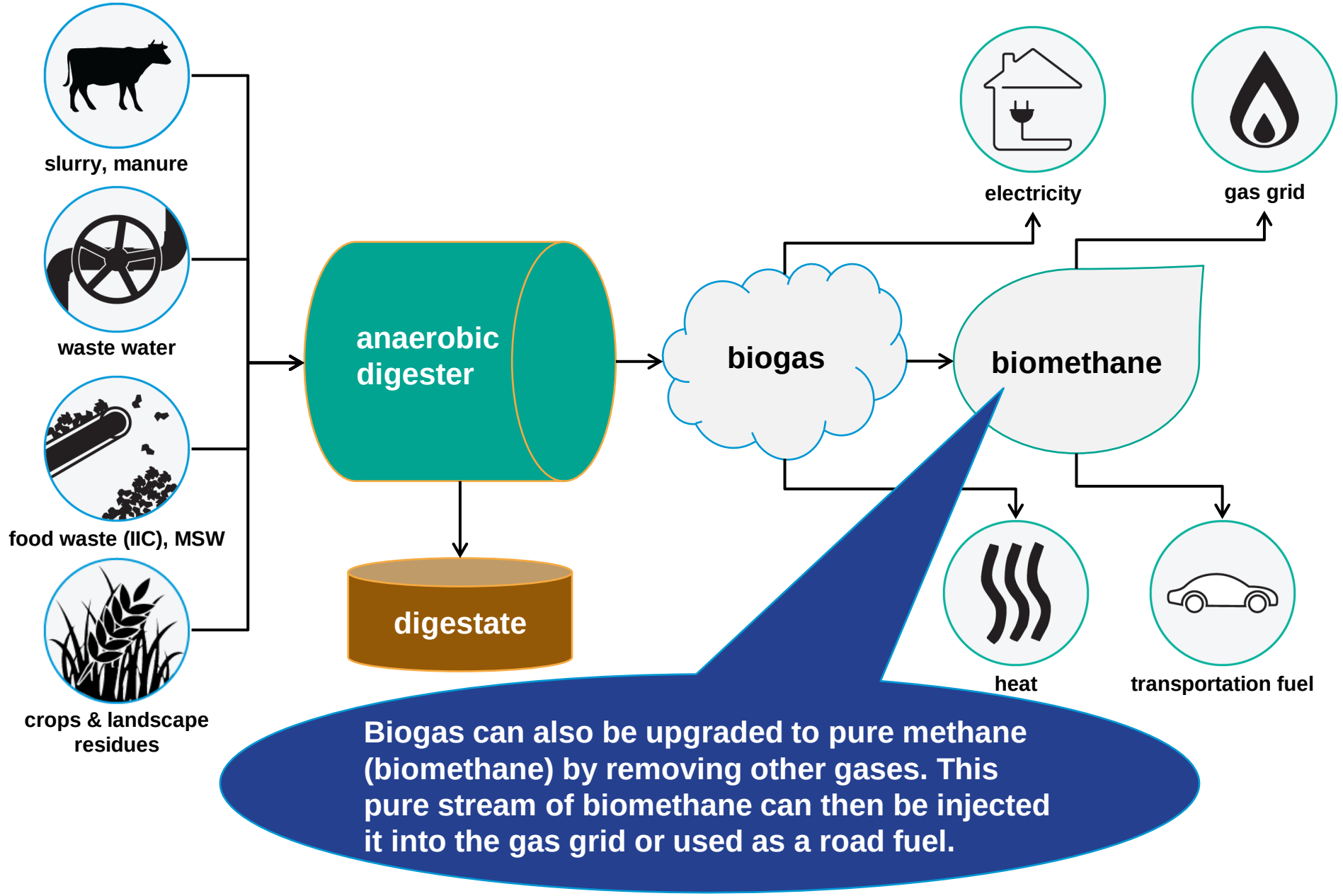
anaerobic digestion: the basics



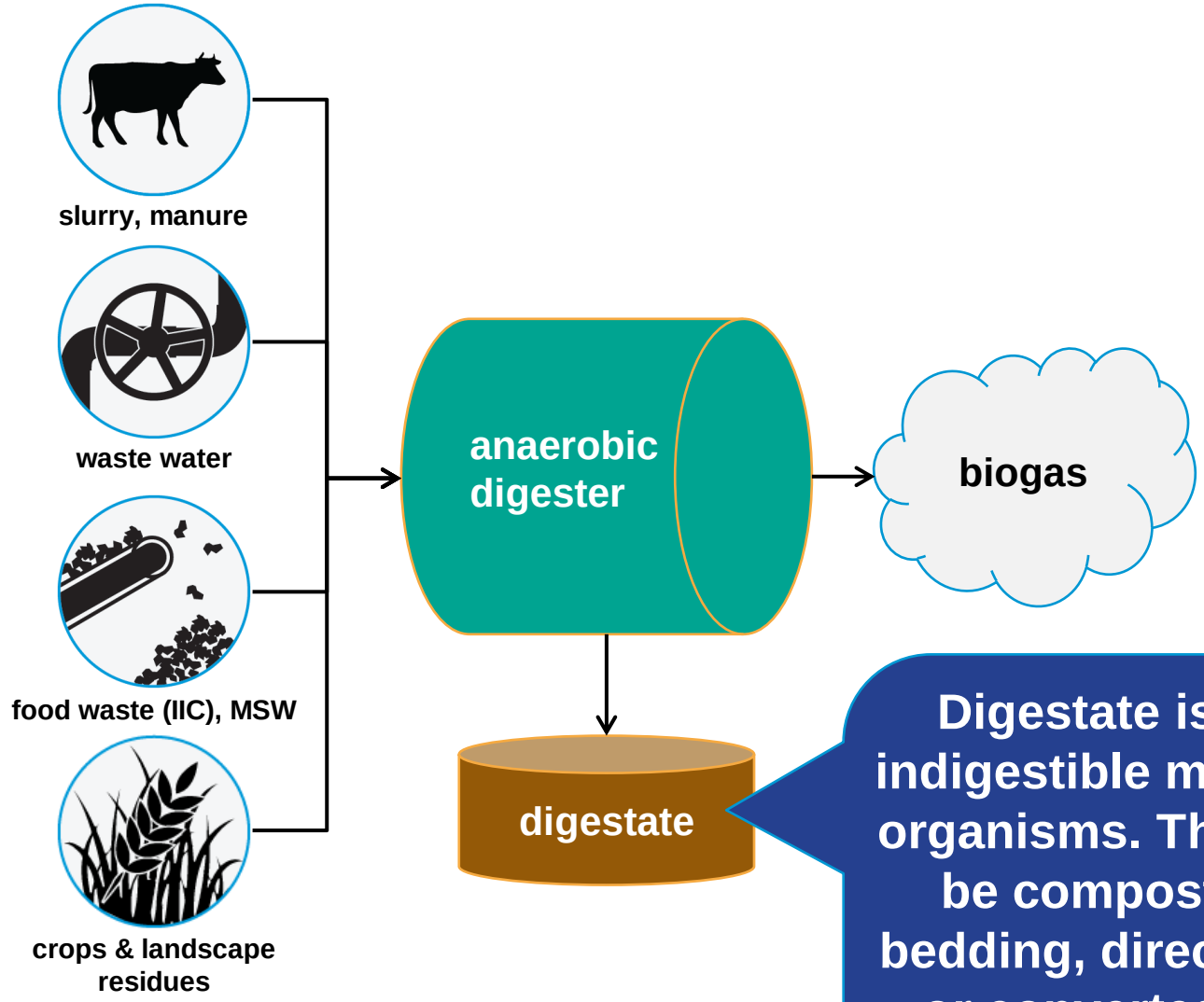
anaerobic digestion: the basics



anaerobic digestion: the basics



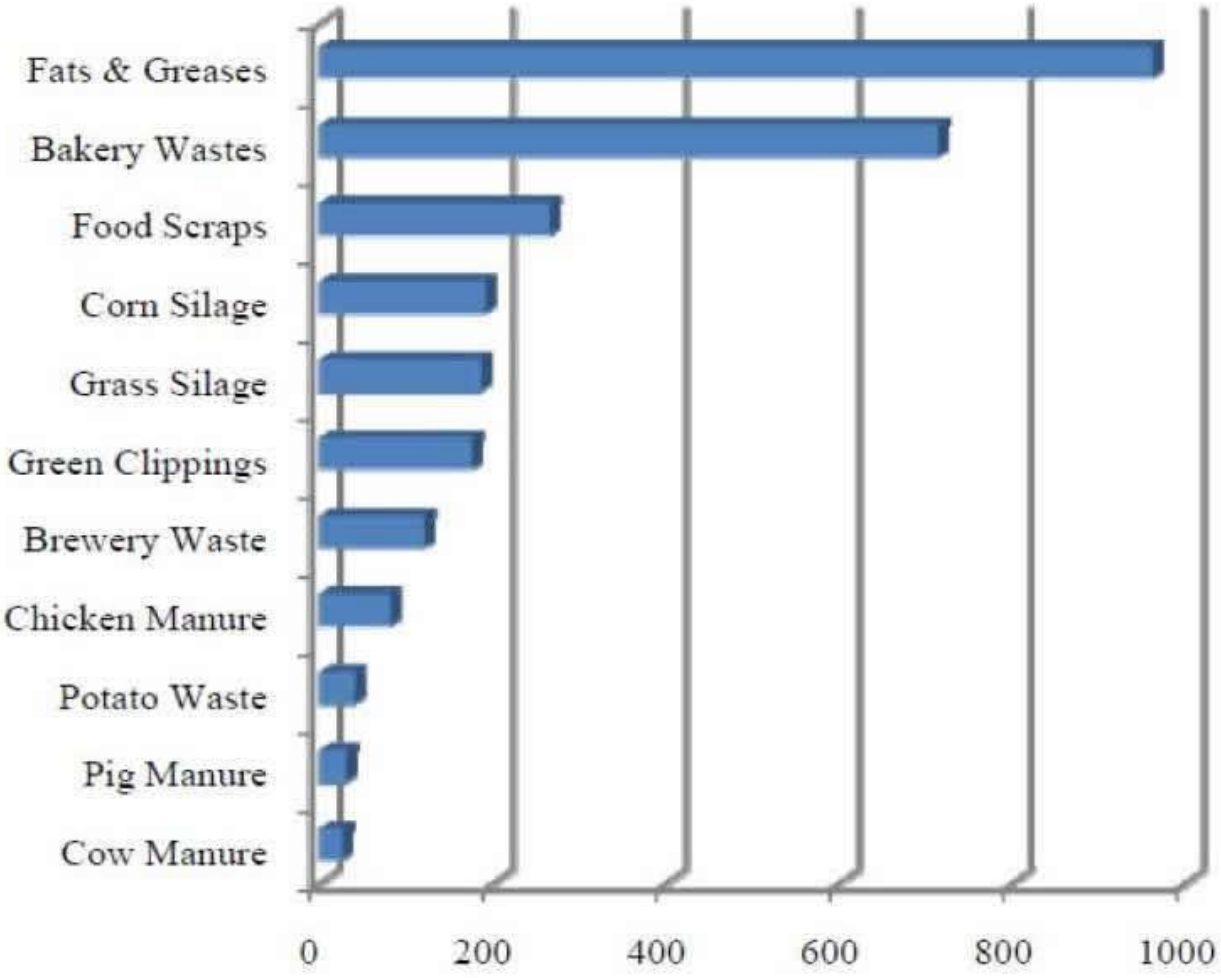
anaerobic digestion: the basics



Digestate is made from left over indigestible material and dead micro-organisms. The separated solids can be composted, utilized for dairy bedding, directly applied to cropland or converted into other products. Nutrients in the liquid stream are used in agriculture as fertilizer

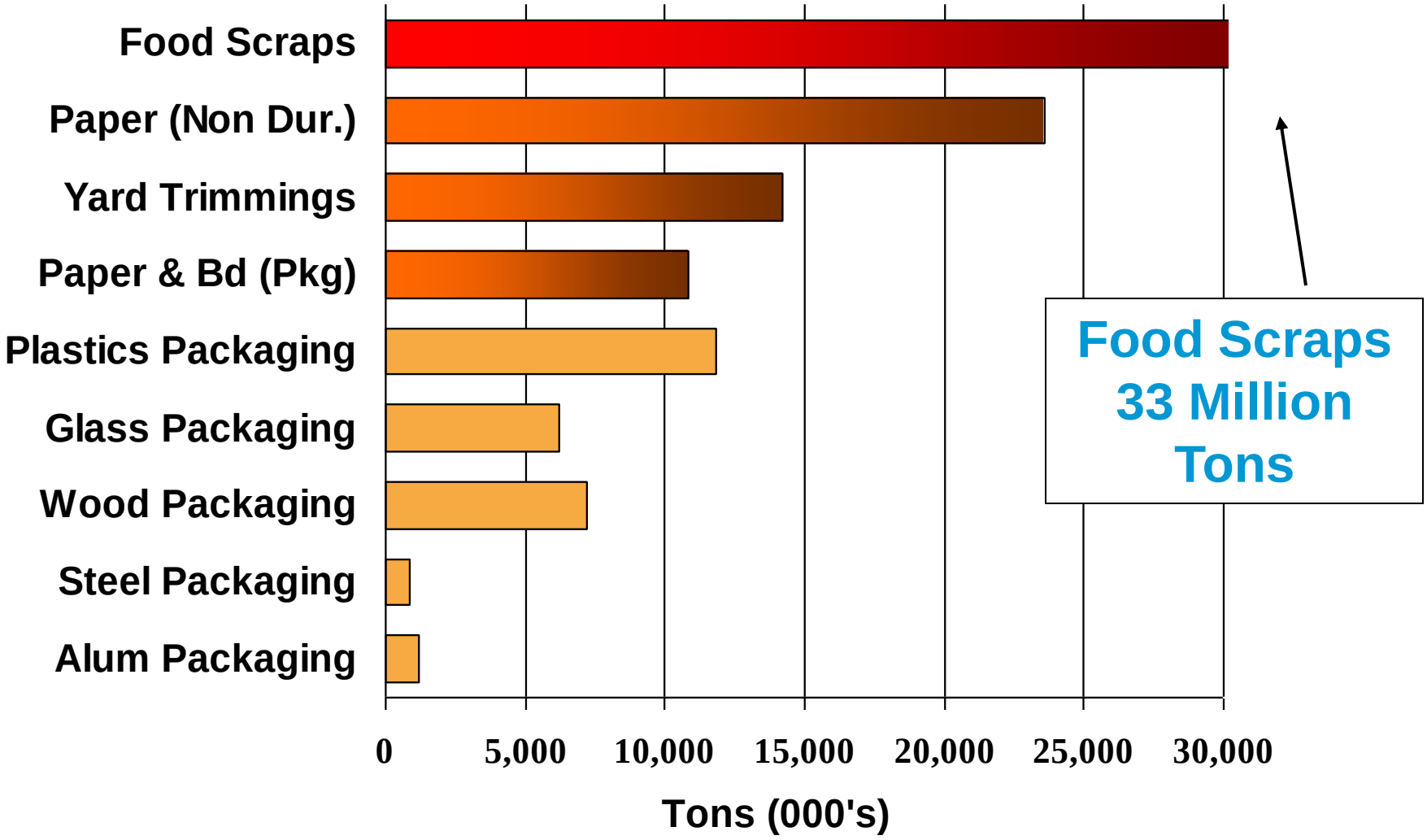
Biogas Source Comparison

what makes the most biogas[11]



Fats, greases & food scraps produce more biogas/lb & are starting to be added as co-feedstocks to wastewater & manure

What is Buried in the US



Source: EPA 2010 Data

AD system types & how bioplastics integrate

Different anaerobic digestion technologies are suitable for different biomass feedstocks

Temperature

mesophilic (25-45°C) or thermophilic (50-60°C)

- Thermophilic systems have a faster through put with faster biogas production per unit of feedstock and m^3 digester. However, the capital costs of thermophilic systems are far higher, more energy is needed to heat them and they generally require more management.

Moisture

wet (5-15% dry matter) or dry (over 15% dry matter)

- Effectively, in wet AD the feedstock is pumped and stirred and in dry AD it can be stacked. Dry AD tends to be cheaper to run as there is less water to heat and there is more gas production per unit feedstock. However, wet AD has a lower set-up capital cost. The trend is towards more dry systems to handle MSW.

Configuration

continuous flow or batch flow

- Most digesters are continuous flow as opening the digester and restarting the system from cold every few weeks is a management challenge. They also generally give more biogas per unit feedstock and their operating costs are lower. Some dry systems are batch flow, however. To overcome peaks and troughs in gas production there is usually multiple batch digesters with staggered changeover times.

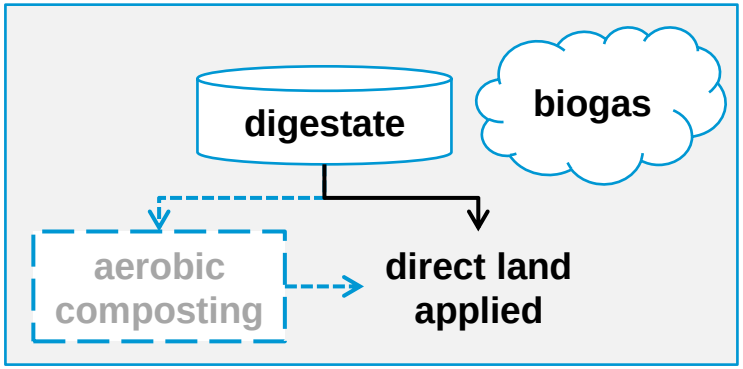
single or multiple digesters

- Some wet systems have multiple digesters to ensure each AD stage is as efficient as possible. Multiple digesters can give more biogas per unit feedstock but at a higher capital cost, higher operating cost and greater management requirement.

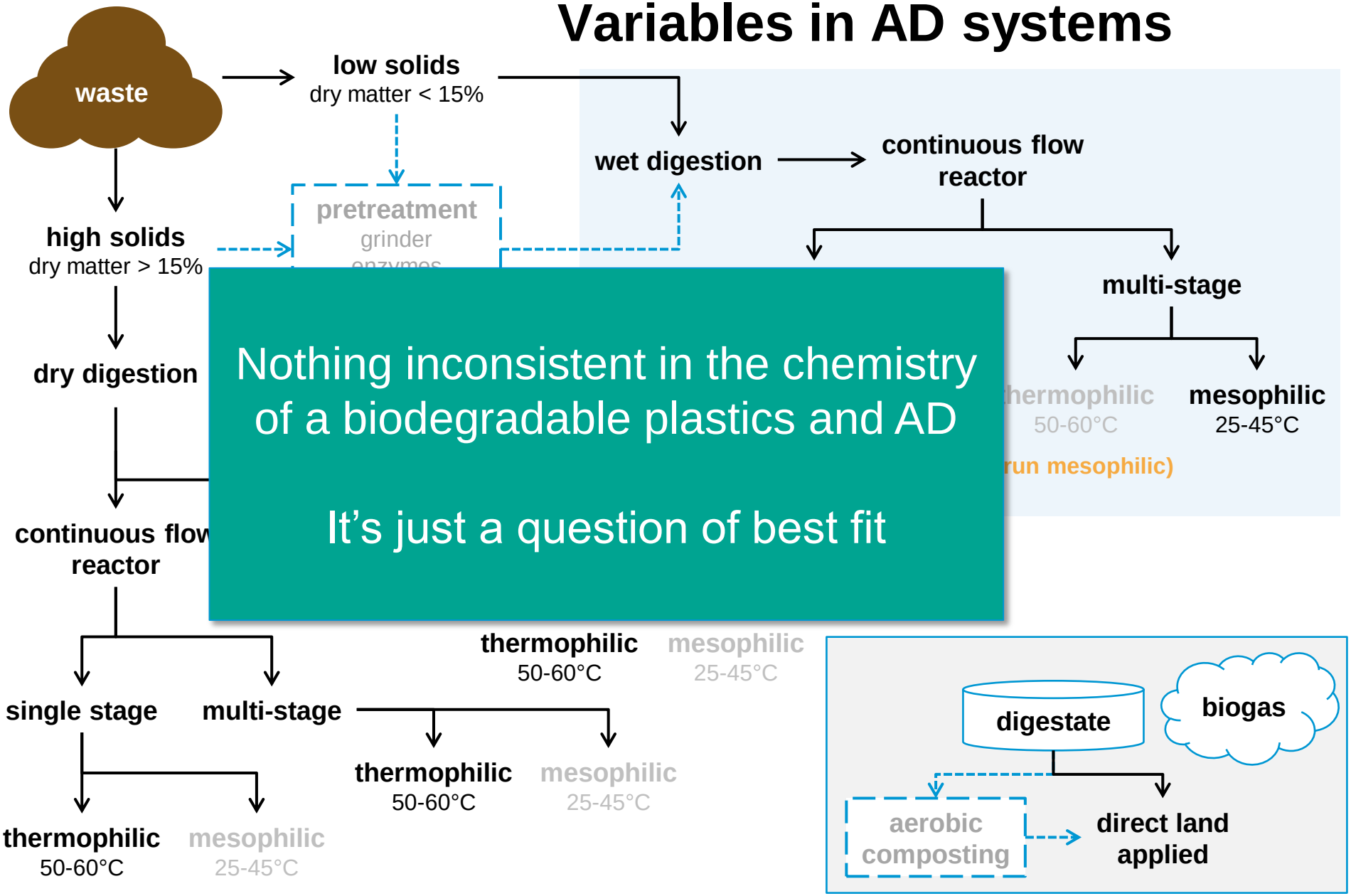
Variables in AD systems

waste

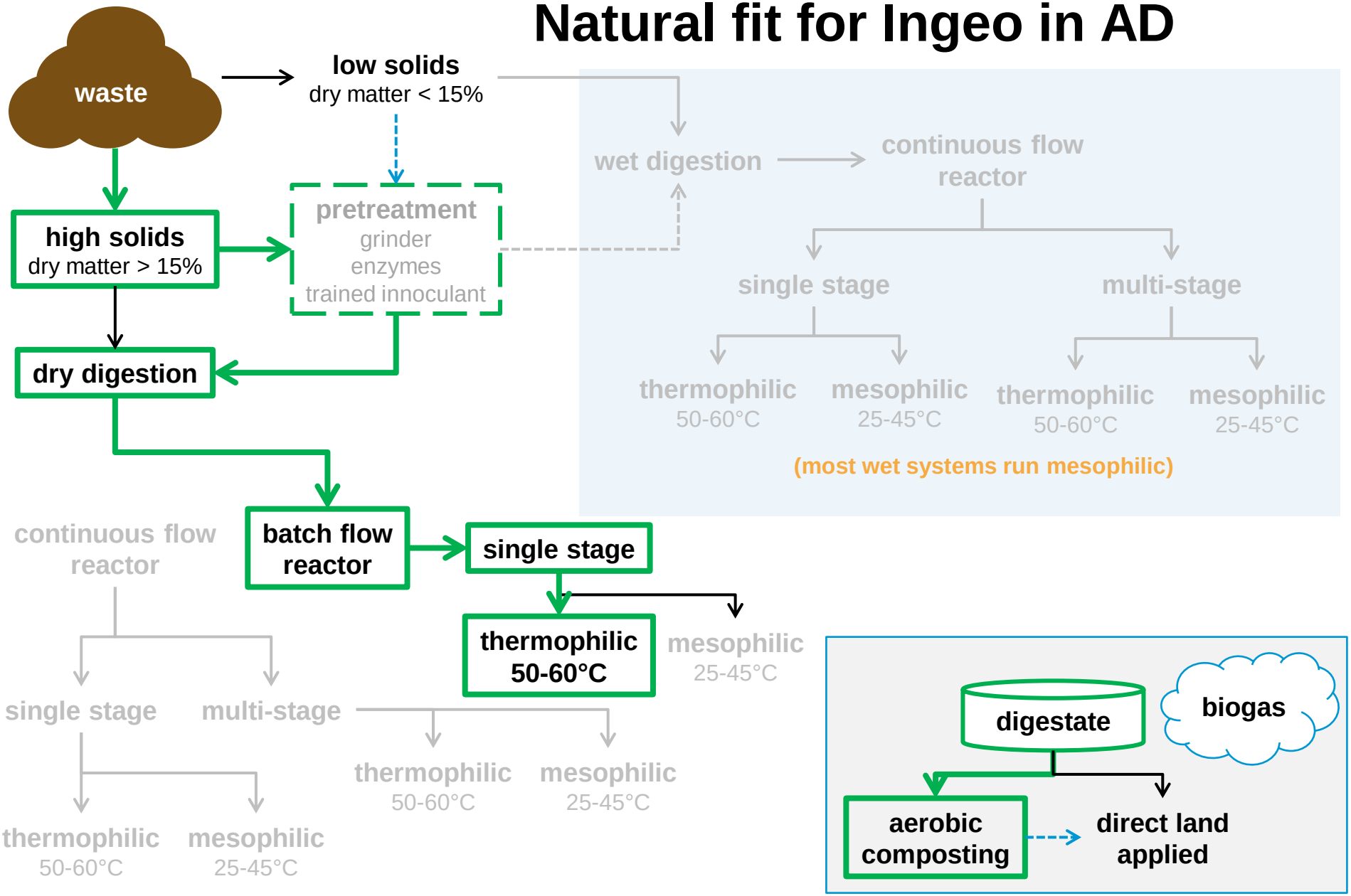
?



Variables in AD systems



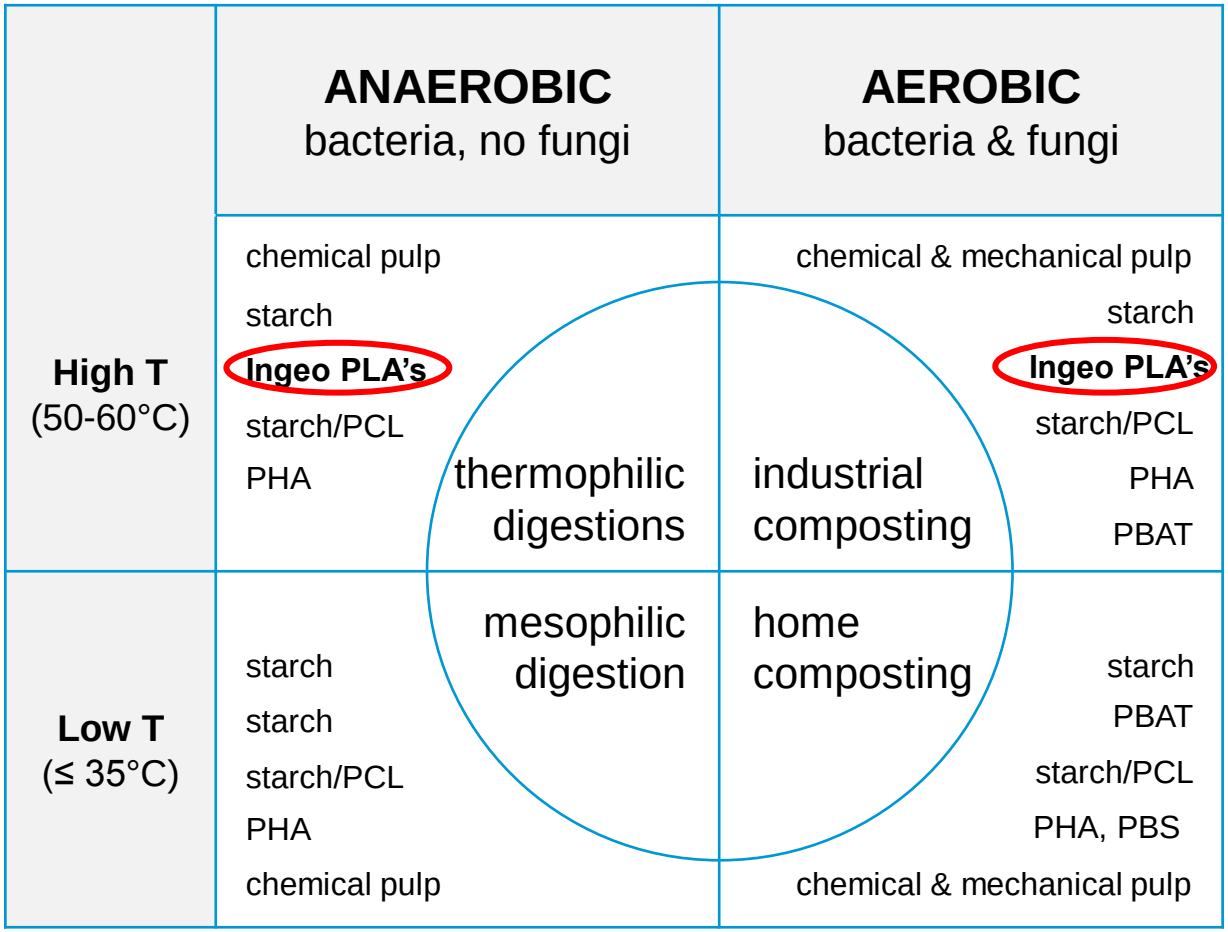
Natural fit for Ingeo in AD



Bioplastics in the Aerobic/Anearobic Landscape[15]

fungi that typically handle larger particle size, are not present in anaerobic conditions.

Rather it's bacteria that are predominately present



Ingeo PLA chemistry requires high temperatures to initiate degradation in both aerobic & anaerobic conditions

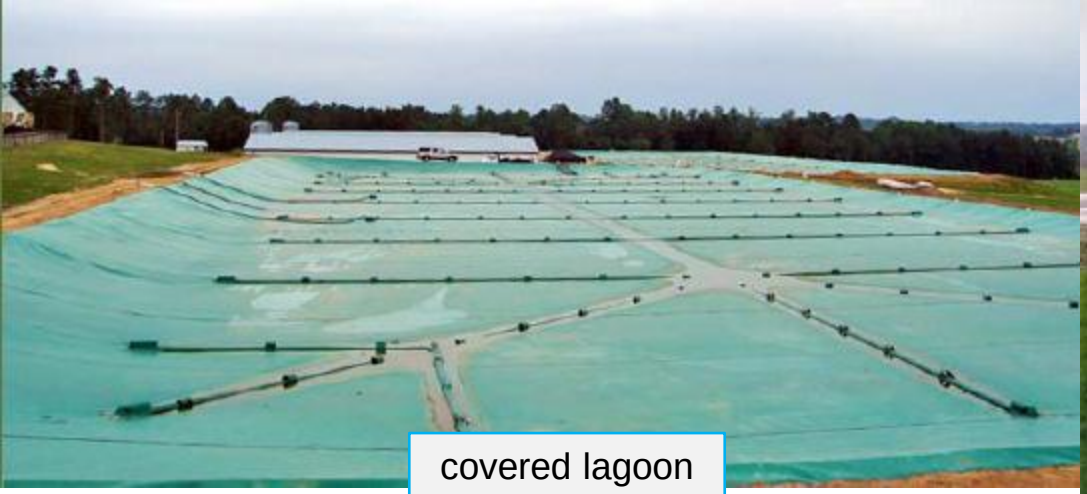
There are many AD system types & many factors that influence what system to use

AD system morphologies

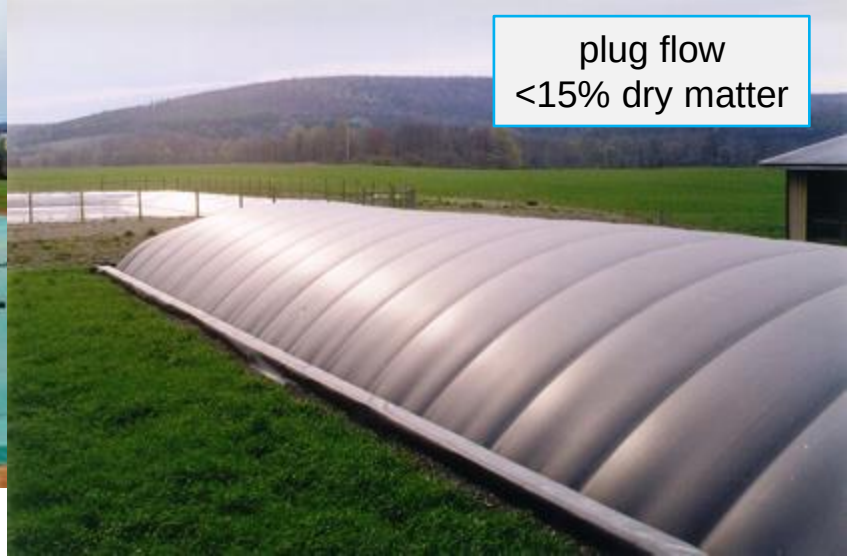
- Batch tunnel digester
- Dry continuous stirred tank (vertical or horizontal)
- Horizontal plug flow
- Vertical wet digester
- Covered lagoon
- Complete mix

factors that influence choice of technology

- Type of feedstock
- Co/single digestion
- Location
  - Ex. need a small footprint near urban areas
- Desired output
  - Ex. biogas, bedding, digestate (for direct land apply)
- Available grants/financing



covered lagoon
<15% dry matter



plug flow
<15% dry matter

batch tunnel digester
45-55% dry matter

dry continuous digester
25-50% dry matter

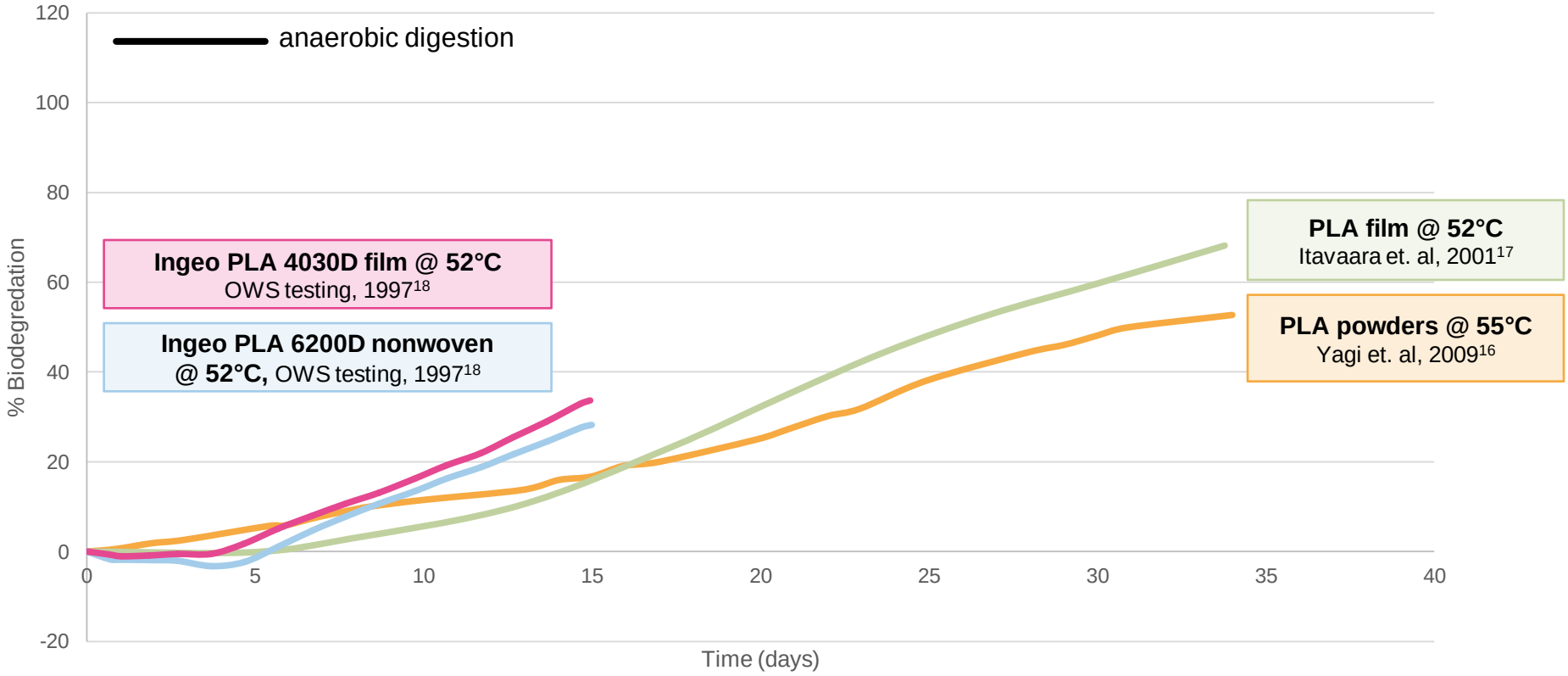
horizontal plug flow
15-30% dry matter

wet digestion
1-15% dry matter

data on Ingeo-based products in anaerobic digestion systems

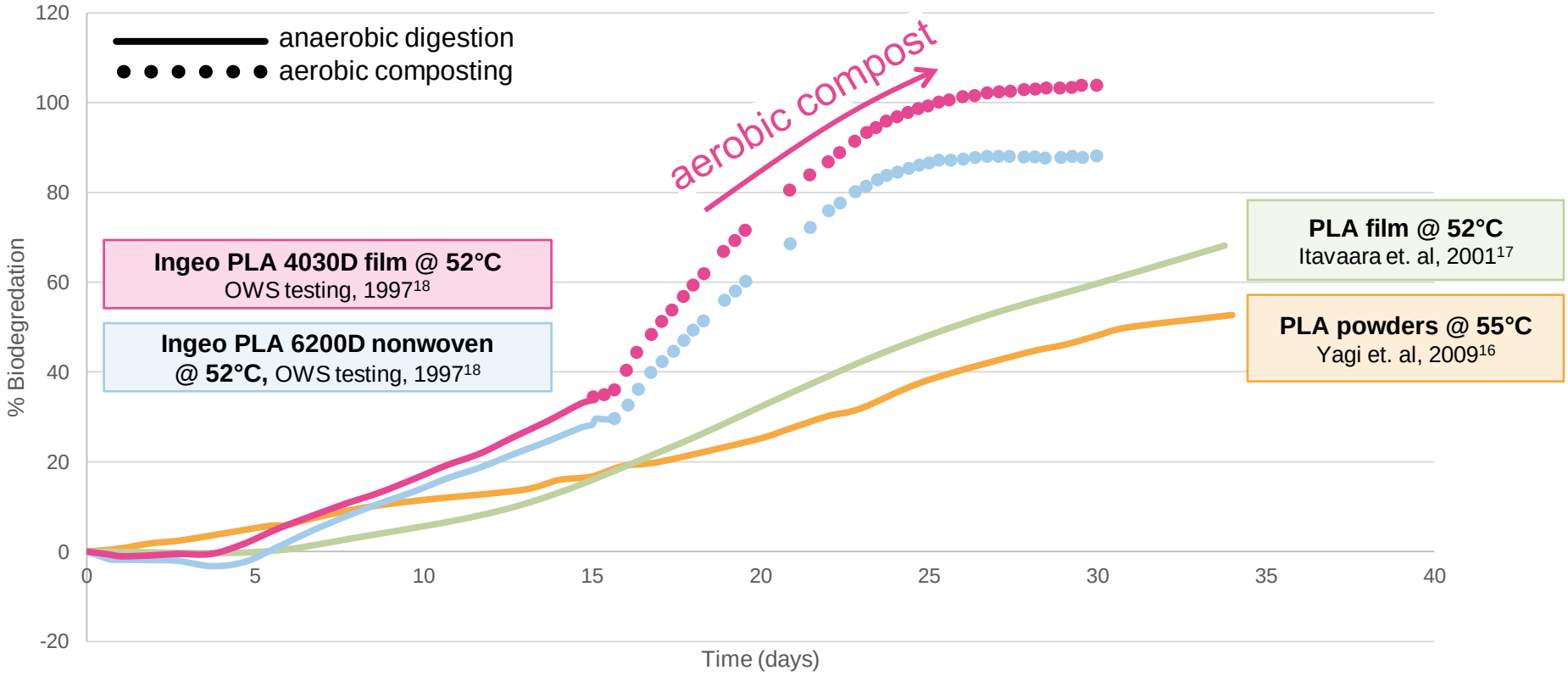
Published studies shows a range of PLA degradation in thermophilic AD conditions

(In mesophilic conditions, Ingeo shows very little biogas generation)



Published studies shows some PLA degradation in thermophilic AD conditions

- Following AD with digestate aerobic composting step achieves 100% biodegradation



In Aerobic Degradation of AD digestate,
Compost time for PLA grades is substantially shortened

Sources

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