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Digester Basics
(aka – Biogas 101)

Paul Greene | Chairman – ABC | Vice President – O'Brien & Gere Engineers

American biogas Council MEMBER

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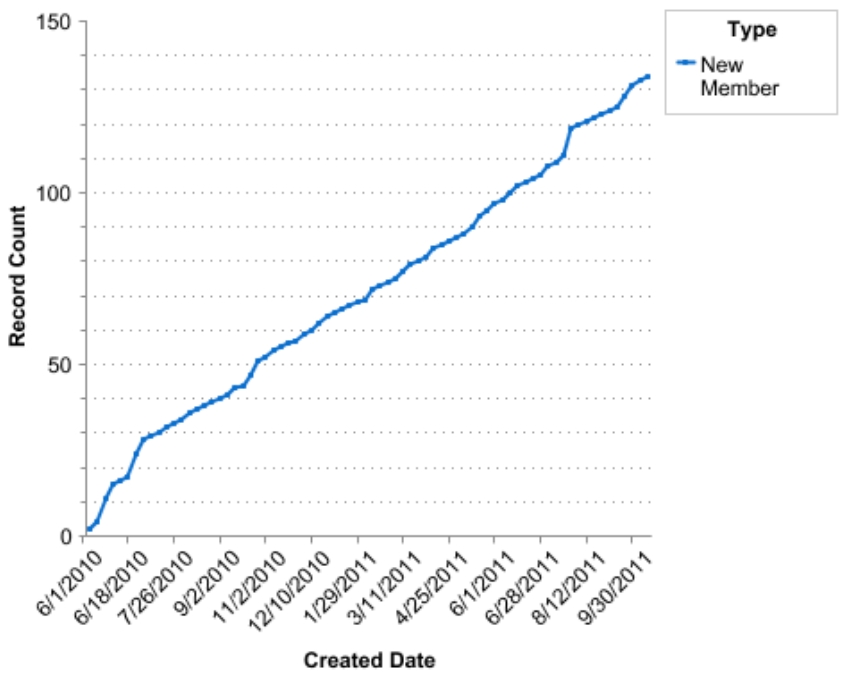
American Biogas Council: The Voice of the US Biogas Industry

- The **only** U.S. organization representing the biogas and anaerobic digestion industry
- **143 Organizations** from the U.S., Germany, Italy, Canada, Sweden, Belgium and the UK
- **All** industry sectors represented:
  - Landowners
  - Fuel refiners
  - Manufacturers
  - Project developers
  - Biogas users
  - Plant owners
  - Financiers
  - EPC firms
  - Wastewater
  - Utilities



Dedicated to Maximizing the Production and Use of Biogas from Organic Waste

Some of members:

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O'Brien & Gere

- Engineering, consulting, and construction management firm
- Building digester technologies imported from Europe for food waste and co-digestion projects
- Developing projects from concept through commissioning
- 1000 Engineers in 25 offices around the East
- Active at many sites in MA currently

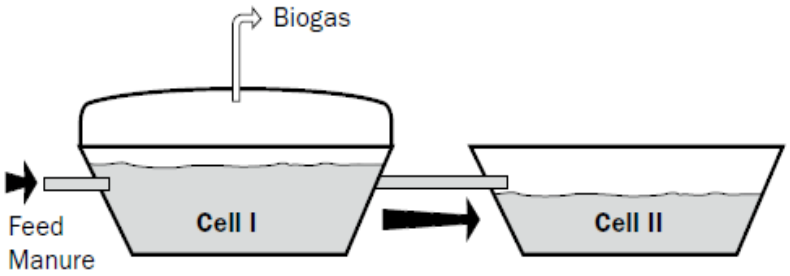
Agenda | Digester Basics

- What is digestion?
- Types of Anaerobic Digestion
  - anaerobic *vs* aerobic
  - liquid train *vs* solid train
  - meso, thermo, TPAD, plug-flow, dry *vs* wet
- What can go into a digester?
  - manure, wastewater sludge, food waste, etc.
- What comes out of a digester?
  - liquids, solids, gases, nutrients
- Why are digesters a good idea from a policy standpoint?
- Why would a farmer / food processor / treatment plant operator want a digester?

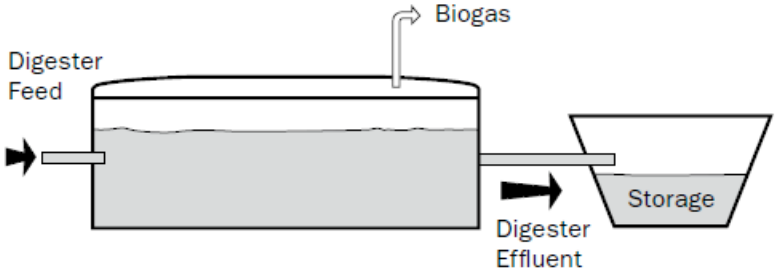
Anaerobic Digester Benefits:

Waste Treatment	Energy	Environmental	Economic
•Biological process •Mature technology •Small footprint •Reduces waste volume •Very efficient and complete decomposition •Nutrient recovery and recycling	•Net-energy producing •Multiple end-uses for biogas: •Heat/electricity/both •Pipeline quality, renewable natural gas •Vehicle fuel •Very reliable •Baseload renewable energy (not intermittent) •Less Power used than aerobic	•Complete biogas/ methane capture •Dramatic odor reduction •Reduced pathogens •Reduced greenhouse gases •Addresses nutrient run-off •Increased crop yield	•Reduced waste volume, reduces costs •Jobs (temporary and permanent) •Balance sheet: changes an expense to revenue •Works well with composting (biogas first)

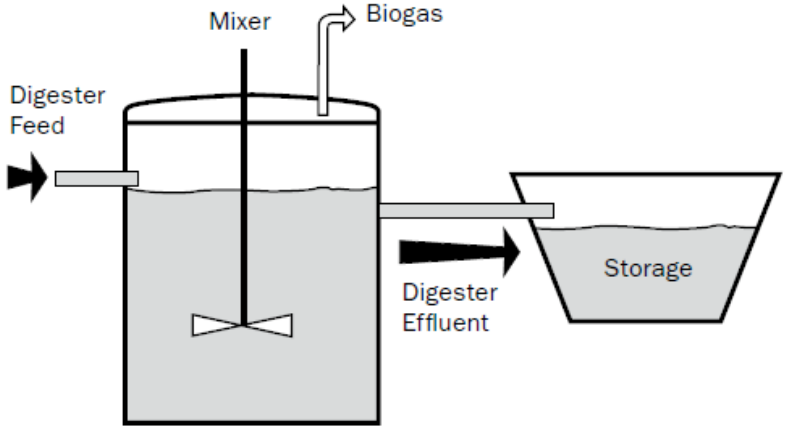
Anaerobic Digestion Technologies



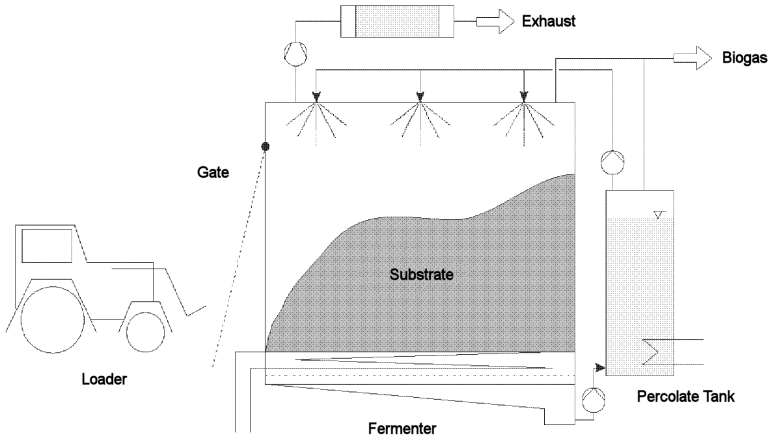
Anaerobic Lagoon
(Ogejo, 2007)



Plug-Flow
(Ogejo, 2007)



Complete Mix
(Ogejo, 2007)

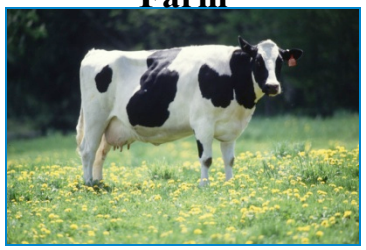


Dry Digestion
(IEA Bioenergy, 2007)

Typical “Wet Digester”

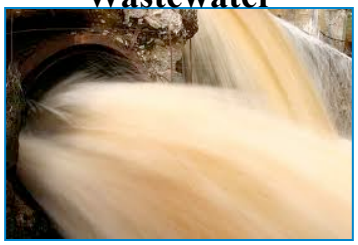
Input:
Any organic waste

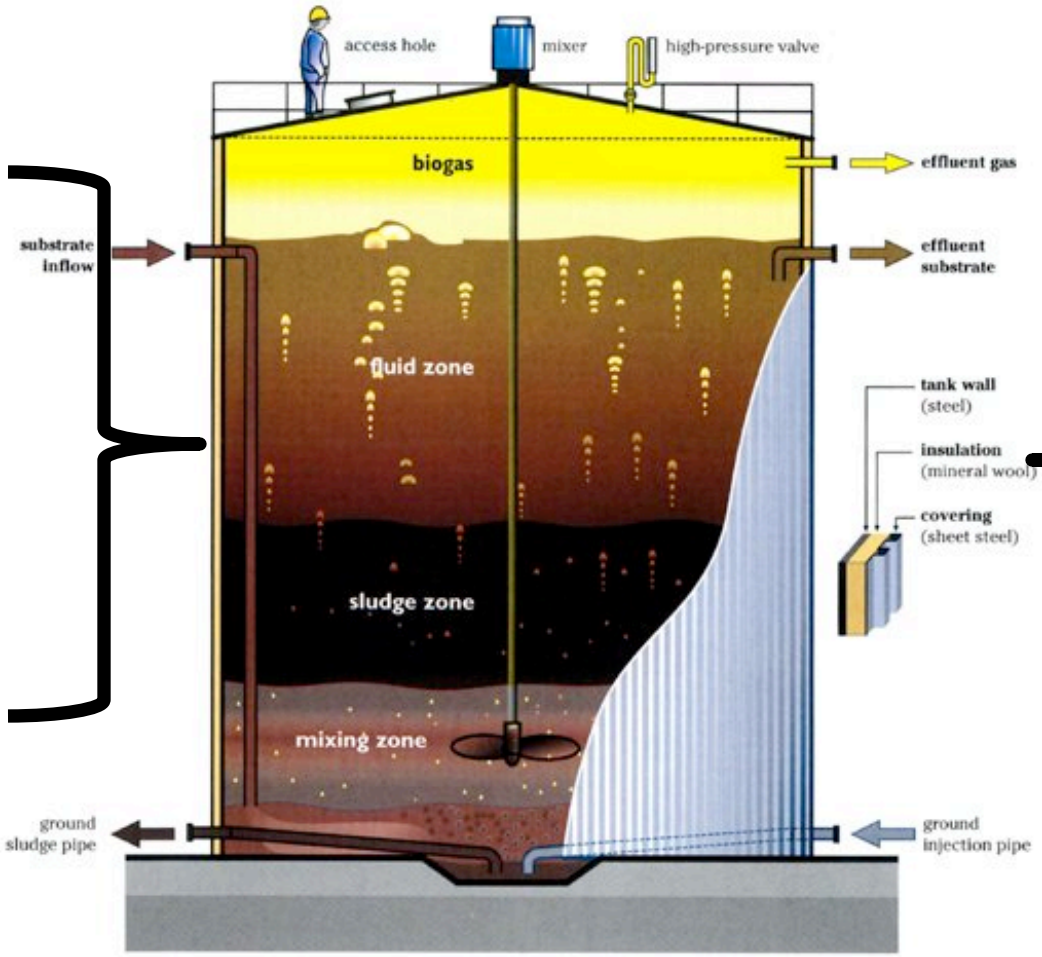
Farm

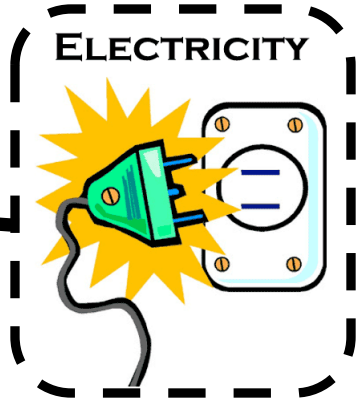


Urban

Wastewater







Anaerobic Digestion | Waste-to-Energy

- Conversion of Organic Wastes to Biogas (Methane and CO_2)
  - High strength soluble organic wastes
  - Other degradable material
    - Food and Food Production Waste
    - Distillery and Fermentation Wastes
    - Pulp and Paper Wastes
    - Pharmaceutical Wastes
    - Fats, Oils, Greases
    - Animal Manure

Steps of Anaerobic Digestion

- Four Stage Process
  - Hydrolysis - Complex organics to simple organics
  - Acidogenisis - Hydrolysis products into short chain VFAs
  - Acetagenisis - Simple organics and VFAs to acetate, CO_2, H_2
  - Methanogenisis - CO_2 and acetate to methane

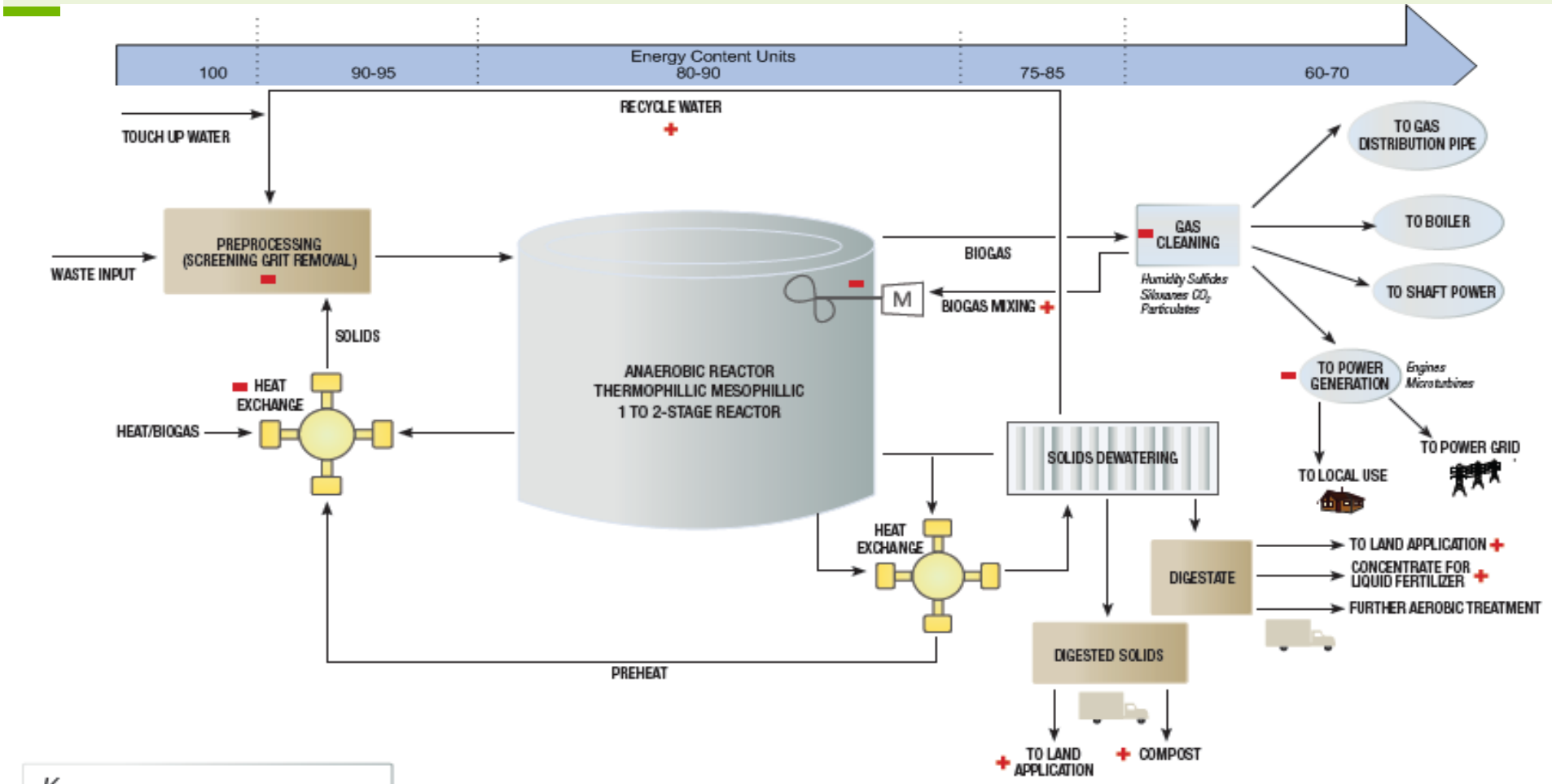
Biogas Generation

- 5.6 Cubic Ft of methane produced per lb of organic material converted
- Biogas is 50-70% methane, 30-50% CO_2
- Dry Heating Value - 500 to 700 BTU/CF

Design Considerations

- Organic Removal Efficiency 60-70%
- Volatile Solids Reduction typically 50-60%

Biogas Renewable Energy



Key

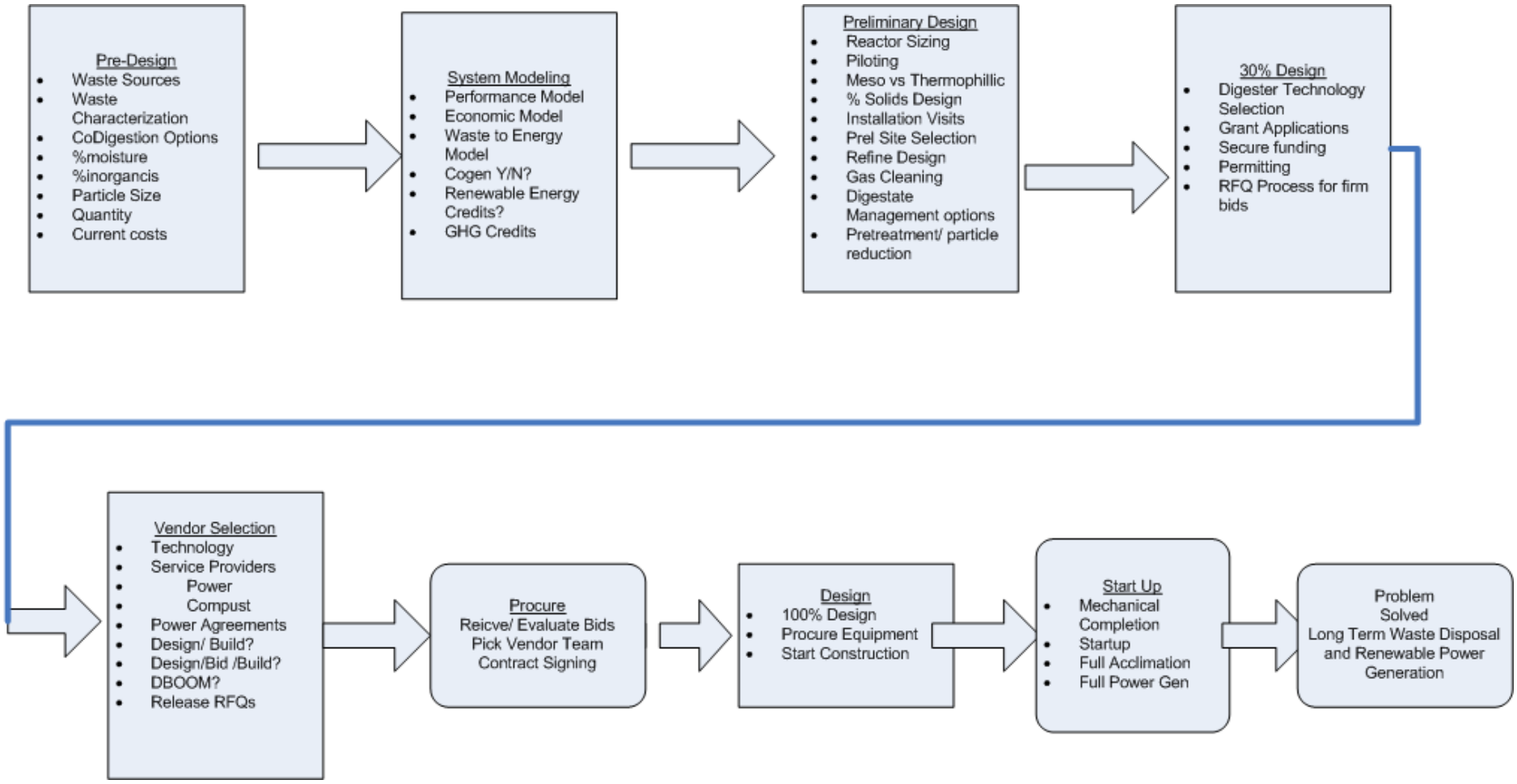
- CANNIBALISTIC POWER LOAD
- BENEFICIAL ENERGY AND RESOURCE RECOVERY

NET BTU/HR OUT = NET BTU/HR (IN) X (EFF OF DIGESTER) X (EFF OF GENSET) – SUM OF (PREPROCESSING + HX + MIXING + GAS CLEANING + DEWATERING)

Digester Temperature Considerations

- Mesophillic (25 to 38 ºC)
  - Moderate loading rate
  - Cleaner biogas
  - Higher yield of microorganisms
  - Larger experience base
- Thermophillic (50 to 57 ºC)
  - Higher loading rate
  - Better virus kill
  - Smaller reactor volume
  - Higher O&M costs
  - Slower yield of microorganisms
  - Fewer installed applications
- TPAD (Temperature Phased AD) – Combination of above
  - Mesophillic systems can also include a short heat treatment / pasteurization phase.

Digester Project Flow



Digester Technology Considerations

E·C·Oregon
Cultivating Renewable Energy Solutions

Feedstock

- Type / Quantity / Seasonality
- Pretreatment
- Storage / Handling / Logistics

Digester Operations & Maintenance

- Parasitic Load
- Feedstock Pretreatment
- Spare Parts Availability

Biogas Plant Technology Considerations

Ancillary Components

- Thermal Use
- Feedstock
- Nutrient Co-Product

Financing

- Process Guarantee
- Feedstock Reference List

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Ancillary Components

- Feedstock
  - Pasteurization / Sterilization
  - Bioseparation
  - Size Reduction
  - Storage / Ensiling
- Nutrient Co-Products
  - Digestate separator
  - Liquid Ccncentration
  - Storage
- Biogas Utilization
  - Boiler
  - CHP
  - RNG
- Thermal Energy Recovery
  - Organic Rankin Cycle Engine
  - Biomass Dryer
  - Greenhouses
  - District Heating

Vendor Evaluations | Example Criteria

E·C·Oregon
Cultivating Renewable Energy Solutions

Digester Performance

- Feedstock Compatibility
- Reference List
- Methane Production
- Organic Loading Rate
- Volatile Solids Destruction

Digester Operations & Maintenance

- Parasitic Load
- Spare Parts Availability
- Annual O&M Expense

Request for Proposal and Budgetary Cost Estimate

Construction / Commissioning

- Team
- Schedule
- Cost Controls
- Shakedown & Verification

Financing

- Process Guarantee
- CapEx
- Training / Support / Warranties

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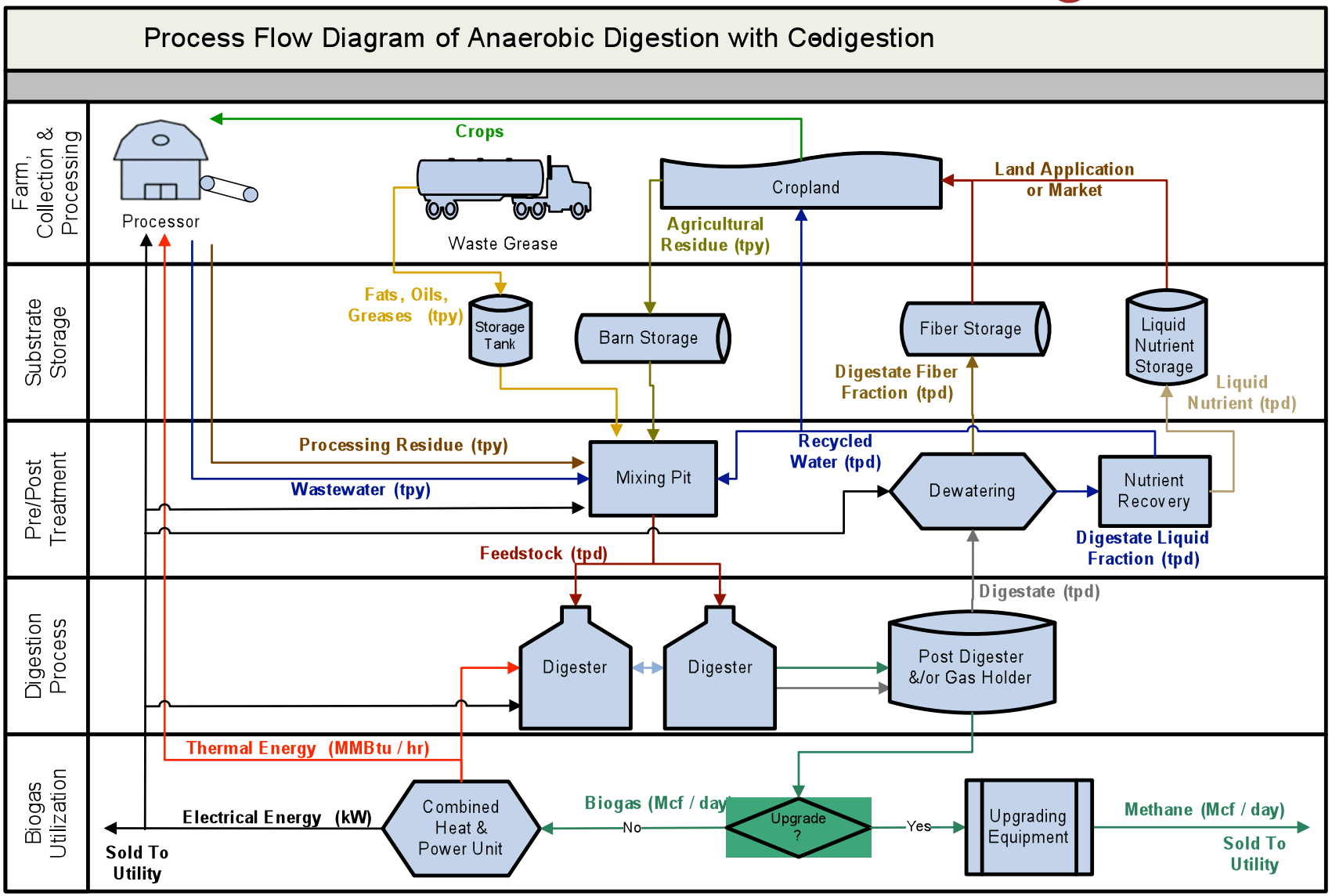
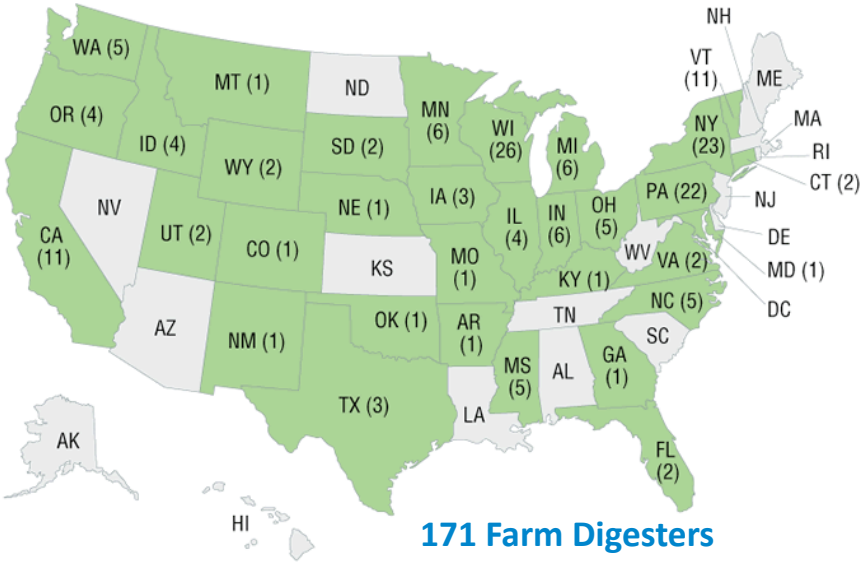
Process Example



2,200+ biogas-producing sites currently operational

- 171 digesters on farms (100 MW)
- 1,500 Digesters at Wastewater Treatment Plants (only 250 use the biogas they produce)
- 563 landfill-based energy projects (26 pipeline, 537 electricity/boiler)



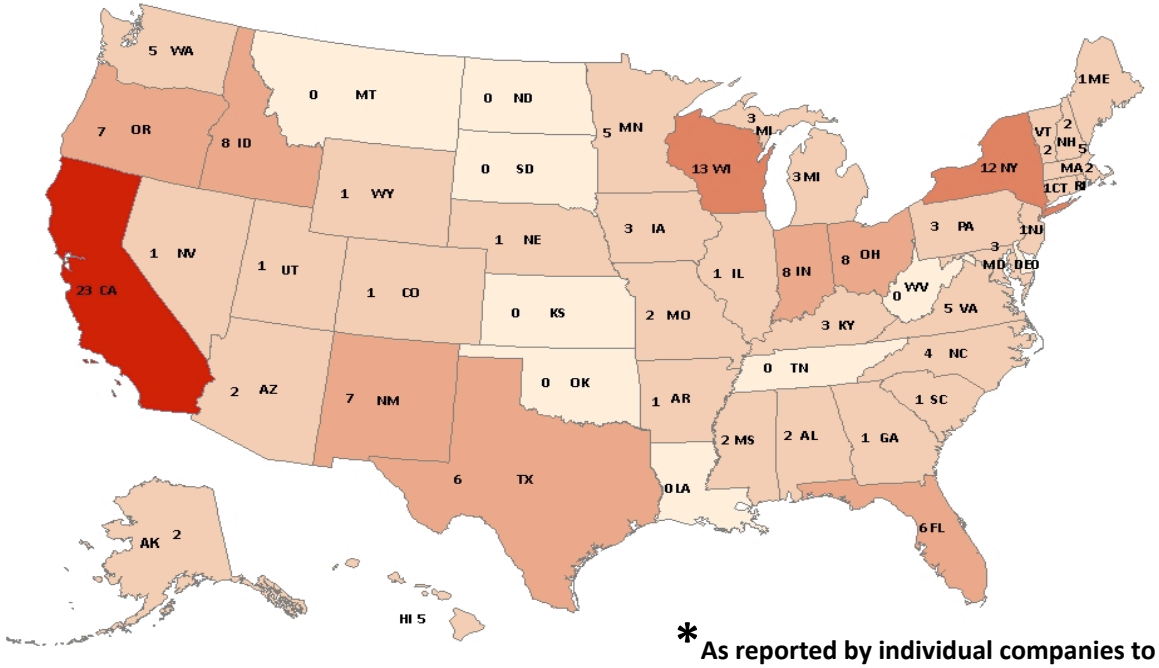
171 Farm Digesters

11,000+ sites available for development

- Farms: 8,200 (only counting dairy and swine)—1700 MW
- Wastewater Treatment Plants (WWTPs): 3,250—750 MW
  - 2,000 WWTPs > 1 MGD don't have a digester
  - 1,250 WWTPs producing, but not using biogas
- Landfills / MSW?

Where Companies are Developing Biogas-Electricity Projects

- Total Projects: 324*
- Total Power Capacity: 649 MW*
- Total Industry Investment: $3.5 billion
- Average: $5.74 million/MW
- Average: $12.6 million/project



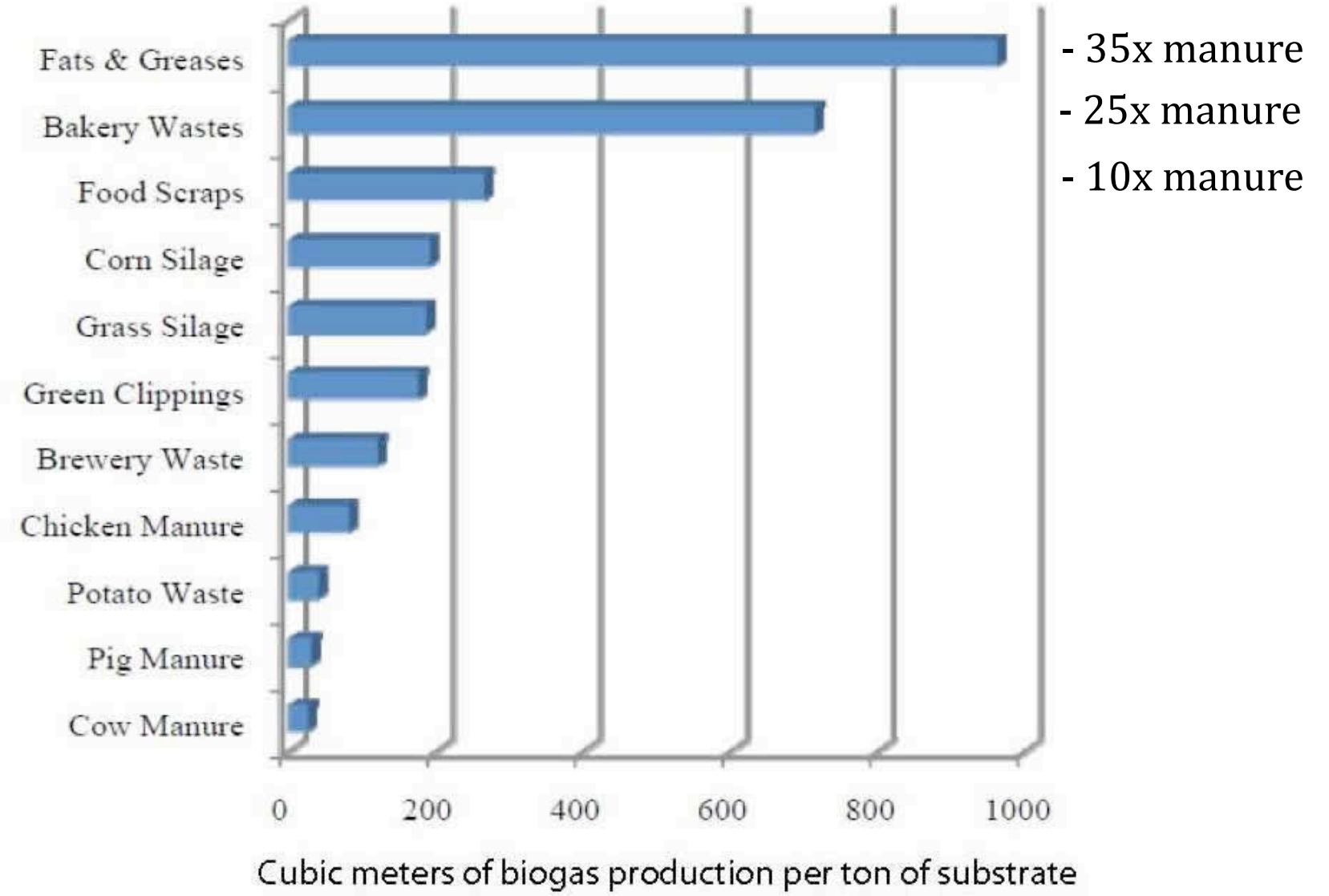
Number of Companies Developing 1603-Eligible Projects Now (Avg projects/company/ state: 2.6)

BS
ojects

- 0
- 1 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25

*As reported by individual companies to the American Biogas Council, Fall 2011

What Wastes are BEST for Making Biogas?

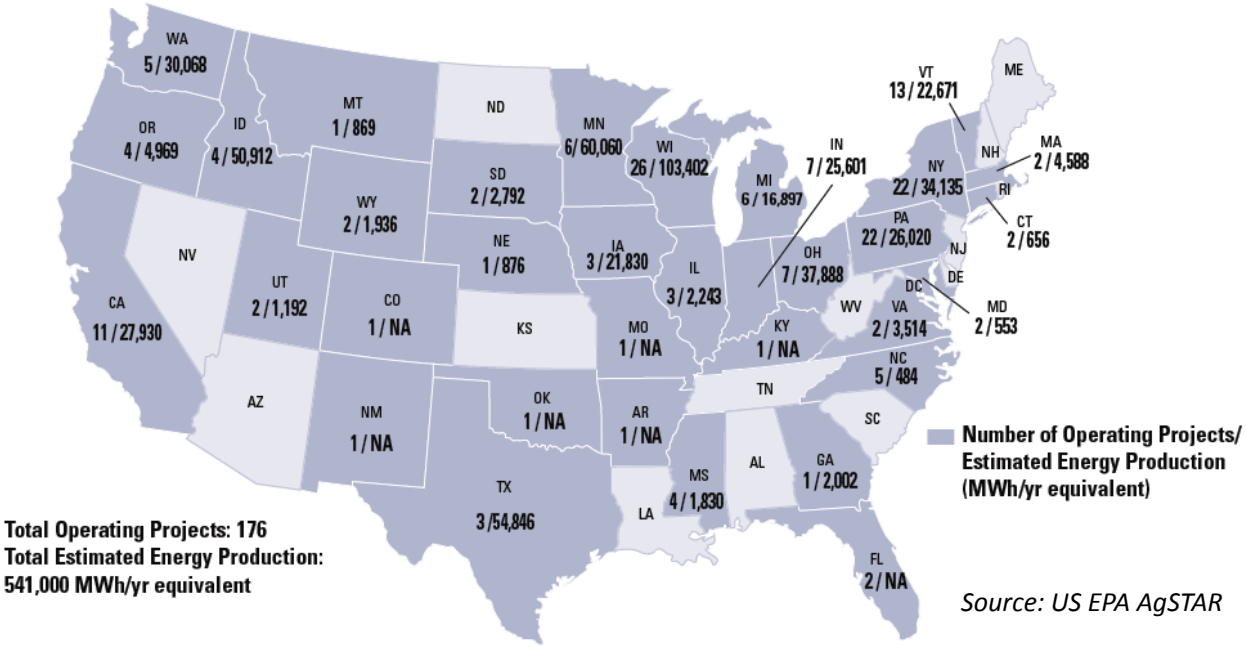


- 35x manure
- 25x manure
- 10x manure

Image source: [Basisdaten Biogas Deutchland]

Farm Based Digesters

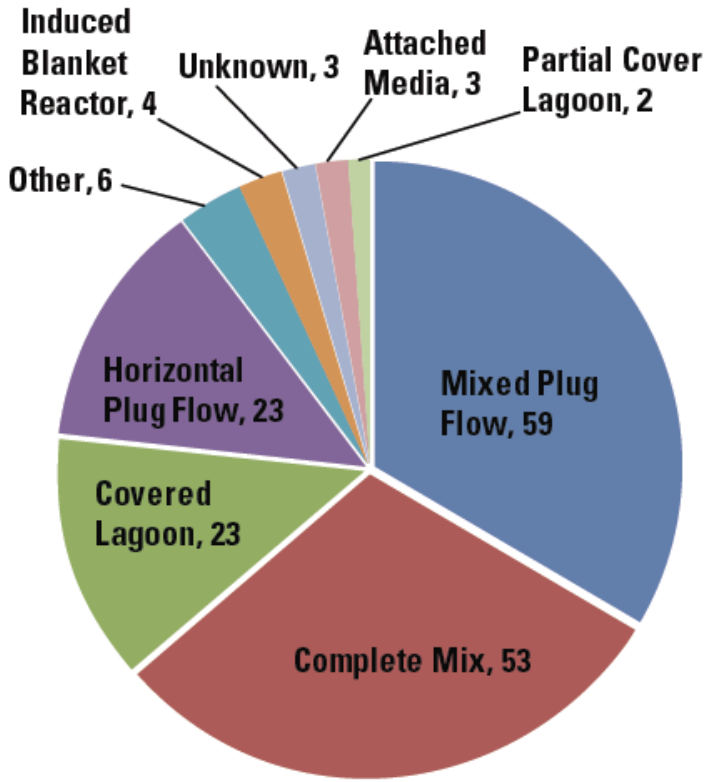
- 176 Digesters on farms
- 541 million kWh of energy produced in 2011
- Increase of kW per project (125 kW to 454 kW)
  - 30% co-digest
  - Larger farm projects
  - Centralized systems



The farm industry is producing more energy!

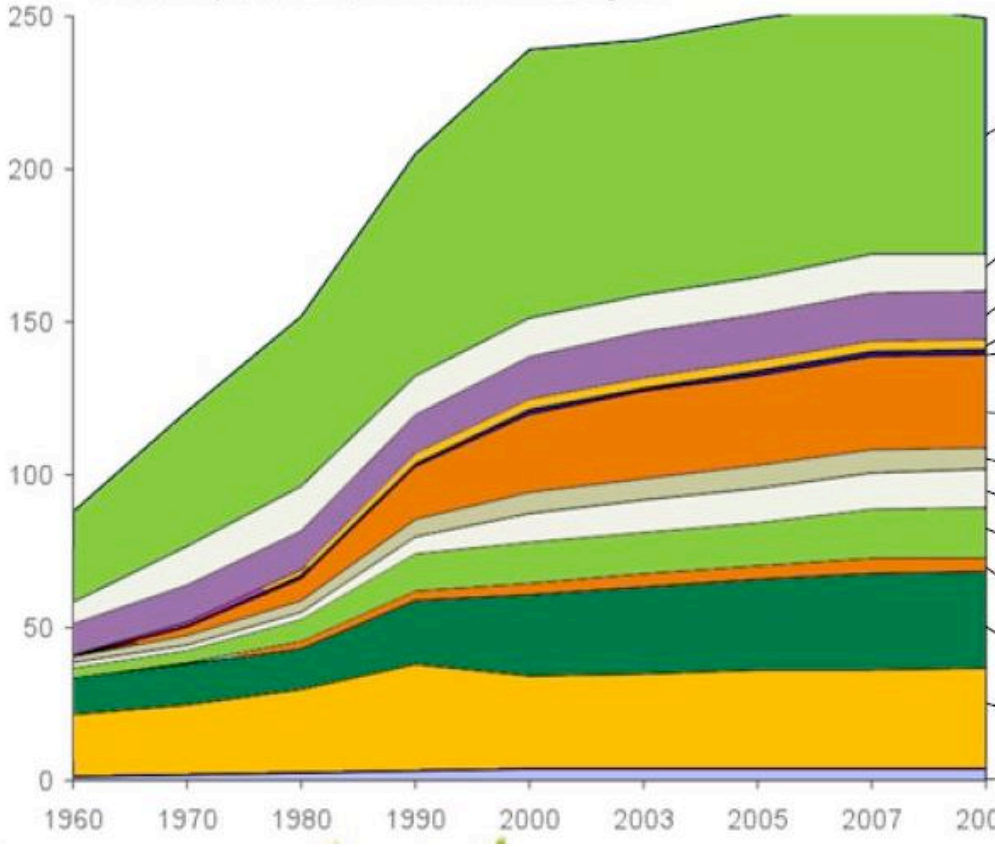
Operating Digesters by Technology

- ~50% of new 2011 digesters were complete mix
- 40% of new 2011 digesters were mixed plug flow



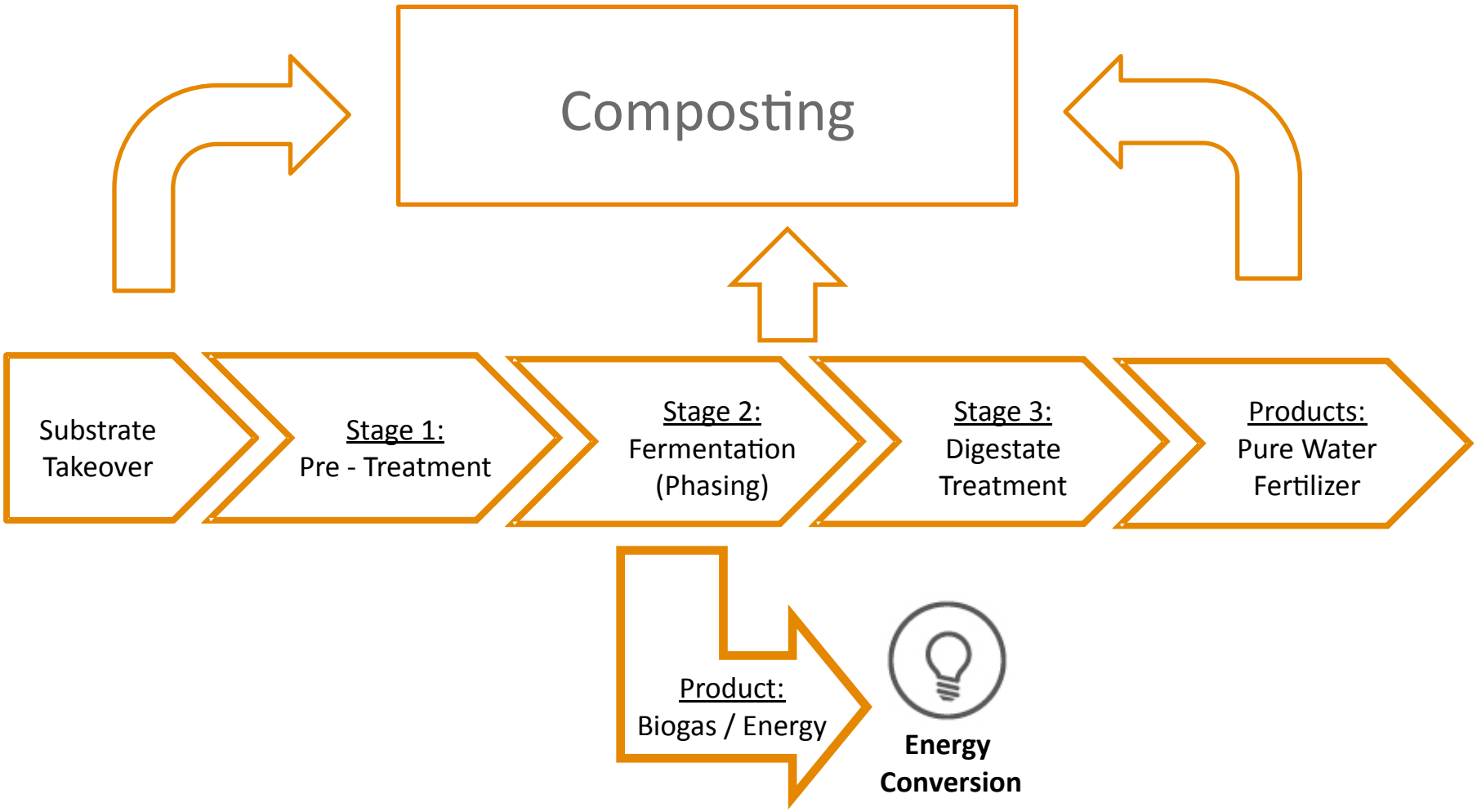
Source: US EPA AgSTAR

Good Digester Feedstocks



	% of Total Generation	
	1960	2008
Paper and paper board	34.0	31.0
Glass	7.6	4.9
Ferrous materials	11.7	6.3
Aluminum	0.4	1.4
Other nonferrous materials	0.2	0.7
Plastics	0.4	12.0
Rubber and leather	2.1	3.0
Textiles	2.0	5.0
Wood	3.4	6.6
Other materials	0.1	1.8
Food scraps	13.8	12.7
Yard trimmings	22.7	13.2
Misc. inorganic wastes	1.5	1.5

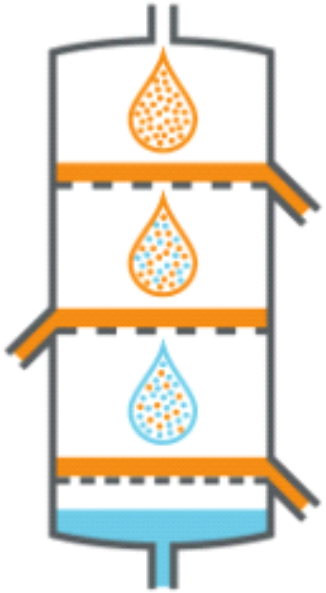
AD Project Process Flow



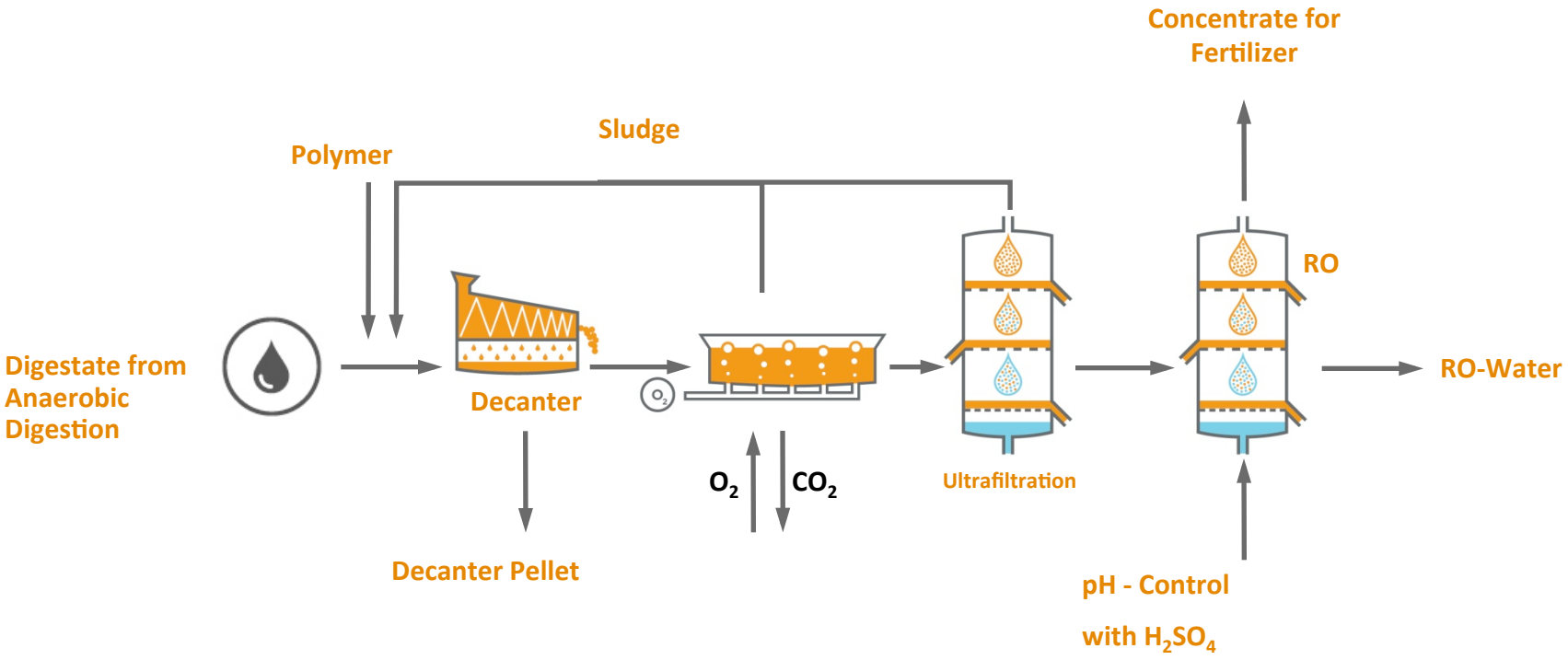
Digestate Treatment

- Digestate Treatment
  - Liquid / Solid separation
  - Aerobic & MBR treatment of waste water
  - Purification through Filtration & RO (optional)

- Key requirements:
  - Nutrient recovery instead of destruction
  - Optimized waste water conditioning for re-use or discharge
  - Solids added to composting operation or sold as fertilizer



Digestate Treatment

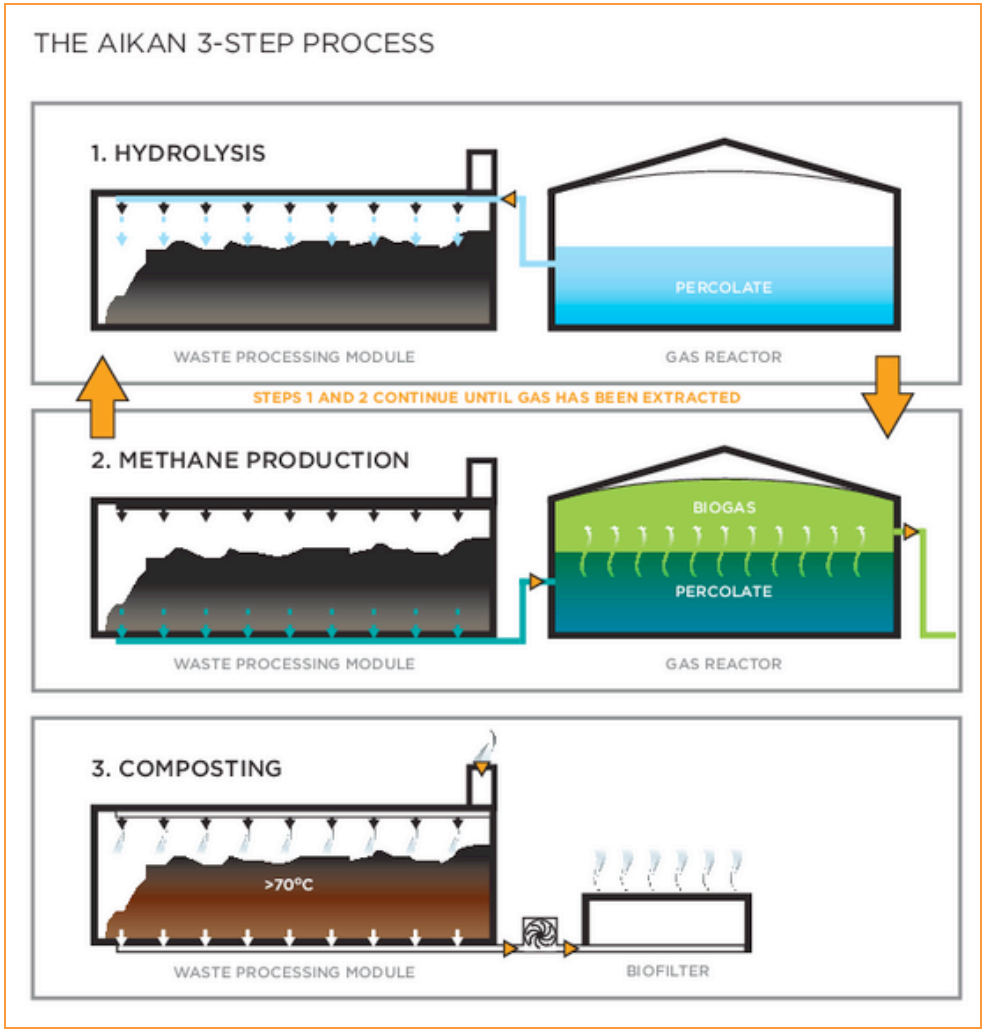


BioGas Project Profitability Factors

- Location
  - Co-Location with composting, landfill, transfer station, WWTP, etc.
  - Reduced cost through shared infrastructure
  - Simplified permitting process
- Tipping fee
  - Critical for profitability
  - Long-term contract
- Energy and product revenue
  - Feed-In Tariff, REC's, RIN's, etc.
  - Fertilizer, compost, clean water
- Proven BioGas technology
  - References
  - Long-term operational data
  - High efficiency
  - Low O&M cost

High Solids | Dry Digestion

- Organic matter that remains after the anaerobic process is complete is called digestate
- Digestate consists of nutrient rich organic matter that can be further biologically processed into high quality compost and soil amendments
- Aikan™ proprietary 3-step integrated high solids anaerobic digestion and in-vessel compost technology to produce not only high quality biogas but also rich, high value compost with significant environmental benefits and a wide variety of uses (e.g., landscaping, nurseries, erosion control)



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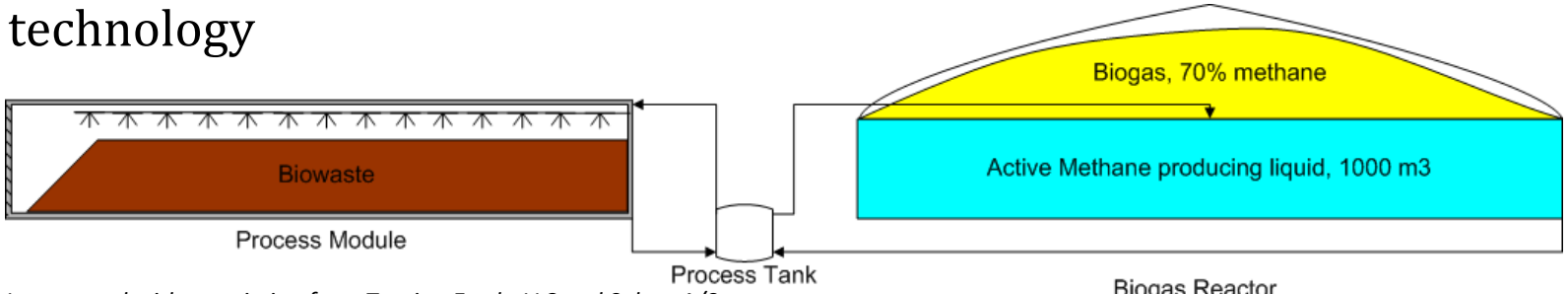
Dry AD | Process

- 3-step integrated high solids anaerobic digestion and in-vessel compost technology



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- Feedstock is loaded into a sealed module and digested on an anaerobic basis
  - Liquid (the "percolate") containing methane producing microbes is continuously recirculated through the biomass and into the reactor tank for biogas generation
- After the conclusion of the methane production period, the biomass (the "digestate") is composted within the same module
  - The digestate is never exposed to environment
  - Air is drawn into the modules creating ideal aerobic conditions
  - The digestate is converted into a high quality compost and soil amendment

Dry AD | Process

- Once the process module is filled, the doors are sealed and the biogas production process commences
- Percolate (the liquid portion of the organic waste) from a nearby percolate tank is sprayed into the biomass from nozzles on the ceiling of the process module
- The percolate washes away nutrients contained in the biomass and drains through drainage holes in the floor of the process module
- From the drainage holes, the percolate is pumped back into the percolate tank

Photo used with permission from Turning Earth, LLC and Solum A/S

Efficient and Proven Process – In-Vessel Composting

- After three weeks of biogas production, the process module commences a composting process within the same chamber

- After two weeks of composting, the process module is emptied and readied for a new batch of feedstock

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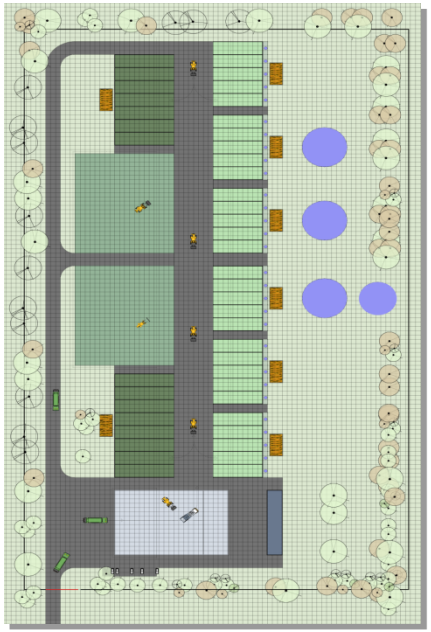
Specifications



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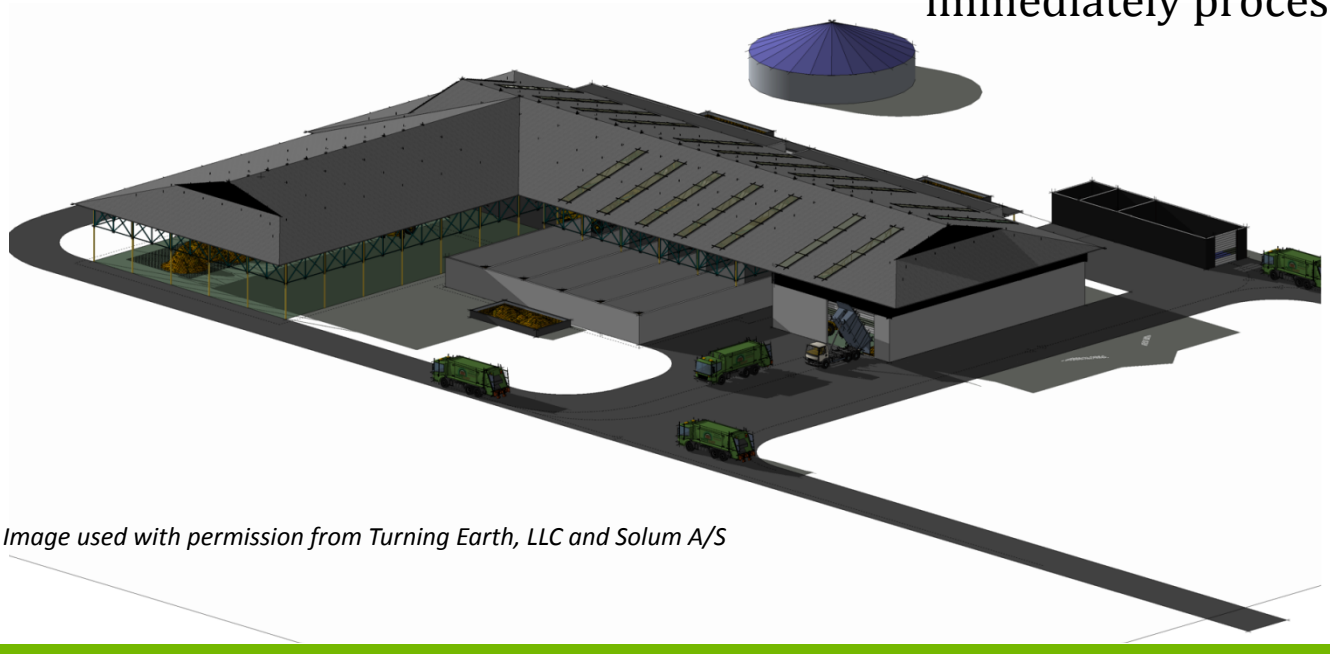
Waste Volume (Annual)	50,000 long tons of organic waste 25,000 long tons of structure
Biogas	141.3 MM cft (4.0 MM m^3) of biogas 98.9 MM cft of methane
Electricity	12,444 MwH (1.6 MW inst. cap.)
Heat	29,710 MM Btu (31,345 GJ p.a.)
Co_2 Reduction	42,500 tons per year
Compost	40,000 cubic yards of organic compost
Footprint	5+ acres

Site Layout & Process Flow

- Trucks enter and are weighed at a scale
- Trucks back into a fully enclosed receiving building which is under negative air pressure for full odor control
- The contents of a truck are unloaded inside the receiving building
- Trucks exit the building and are weighed on the way out of the facility
- The newly received biomass is immediately processed



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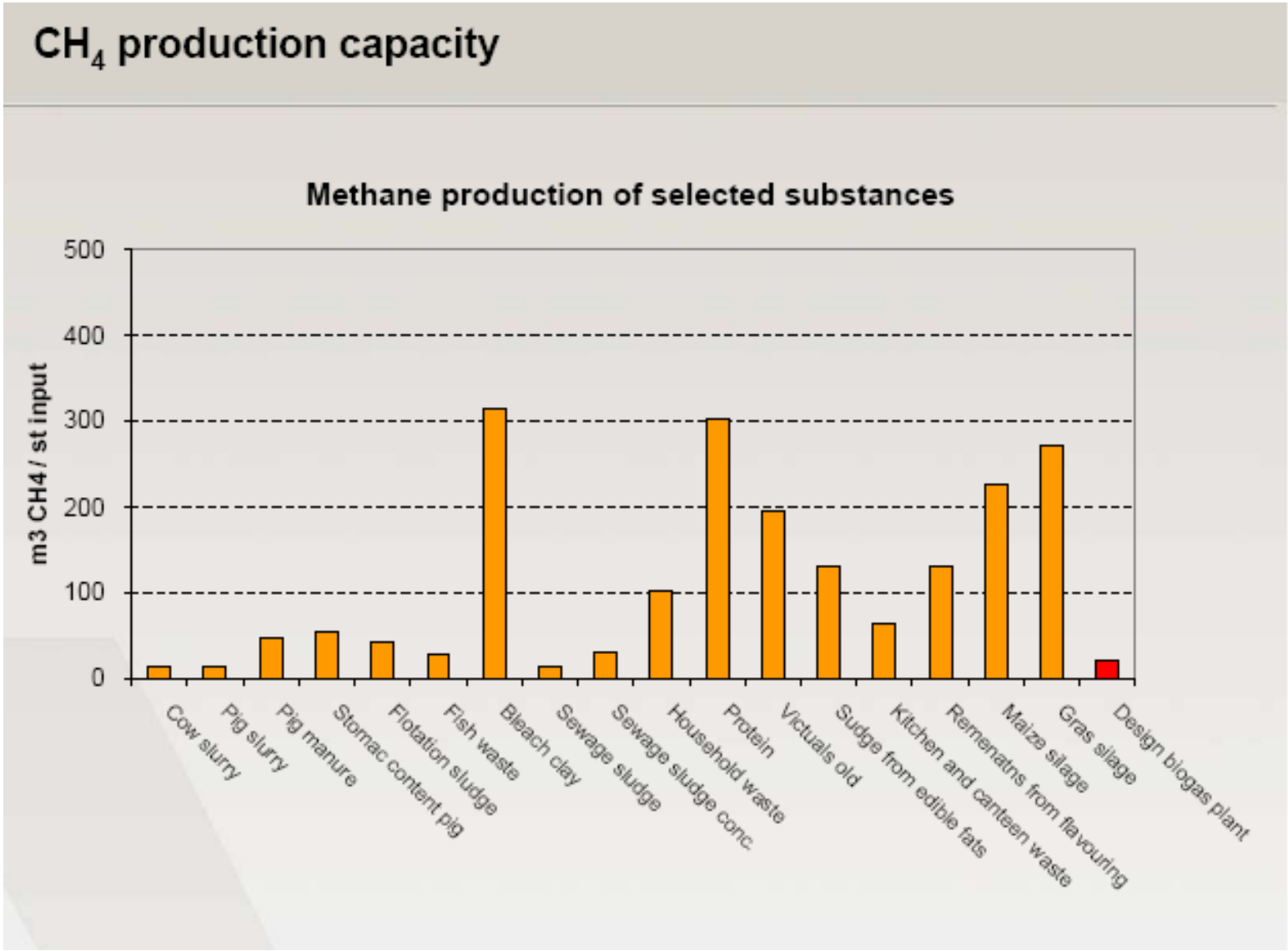
Project Considerations for Success

- Feedstock supply
  - Long-term feedstock (substrate) availability at predictable tipping fees
- Product Off-take (Energy, Fertilizer, Water)
  - Long-term off-take contracts at predictable pricing for all products
- Environment / Permitting
  - Co-location with existing facility (e.g. composting, landfill, etc.)
- Operations & Maintenance
  - Predictable cost
  - Long-term history with proven technology
- Waste-to-Energy Technology
  - Proven with extensive performance guarantees and LD's
- EPC responsibility
  - Guaranteed maximum price, schedule guarantees

Methane Production Capacity



Drivers for Digester Projects

- Increasing waste disposal cost
- State Renewable Energy Portfolio standards
- Increasing costs for hauling waste
- Lower prices for food wastes for animal feed applications
- Non-acceptance of food waste for landfill or land application
- Increasing costs of plant utilities
- Increased interest in:
  - Renewable energy sources
  - Possible GHG emission credits
  - Corporate sustainability initiatives
  - Being “Green”
- Ability to purchase systems on an outsourced DBO or DBOO basis (aka “PPA”)

Policies Currently Helping the Biogas Industry

- **Farm Bill programs** – 2008 Energy Title, especially REAP (Rural Energy for America Program), as well as conservation and other financing programs
  - REAP: 19+ "new" grants announced last week. (See ABC website: www.americanbiogascouncil.org/media_news.asp
- 2007 Energy Bill – Provides incentives for the use of biogas as a transportation fuel
- **Section 1603 Treasury Grants** – allows owners of property qualifying for a tax credit in Internal Revenue Code Section 45 or 48 to receive a 30% grant from the U.S. Treasury in lieu of the tax credit
- Federal Renewable Energy Production Tax Credit (PTC)- per kilowatt-hour tax credit for electricity generated by qualified energy resources including biogas. Under Recovery Act modification a facility which would qualify for the PTC can elect to take the Investment Tax Credit instead, but only if it is an electric generation facility

Policy Gaps and Opportunities

- Establish **parity** for biogenic energy in all federal programs
- Establish an **investment tax credit** for biogas facilities that does not require onsite electric generation
- Ensure continued funding for Farm Bill energy and conservation programs (i.e., REAP, etc.)
- Extend Section 1603 deadlines, and underlying tax credits.
- Increase flexibility for states to regulate buyback prices for renewable energy generation, by supporting PURPA Plus
- Support Rep. Doggett's HR.66 Waste to Energy bill for biogas facilities using wastewater or municipal waste
- Support the NAT GAS Act for natural gas vehicles (upgraded biogas = renewable natural gas)
- Ensure that biogas is fairly treated in any Federal Renewable Energy Standard or Clean Energy Standard
- Encourage expansion of DOE Biomass Program to include biogas technology

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THANK YOU

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