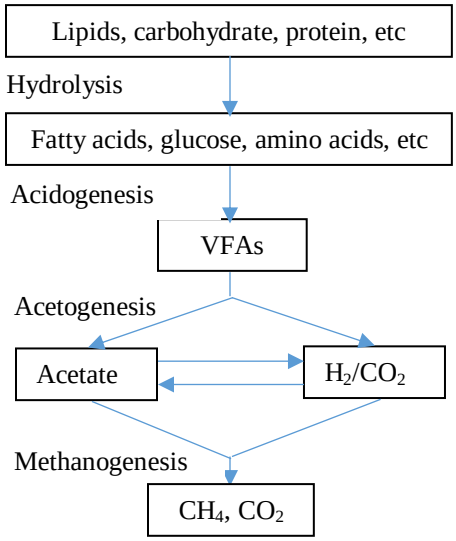


Fig. S1. Anaerobic digestion processes, adapted from Zhang et al. [1].

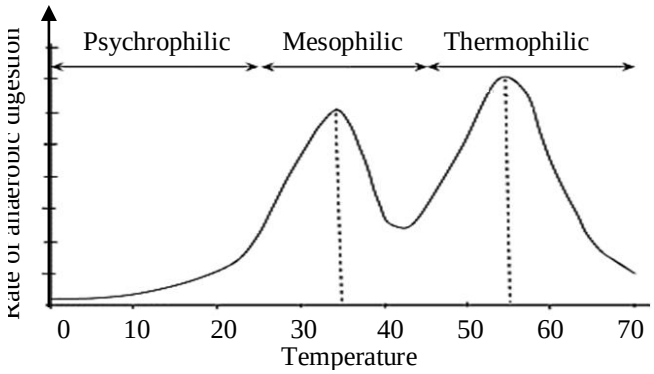


Fig. S2. Effects of temperature on the rate of the AD process [2].

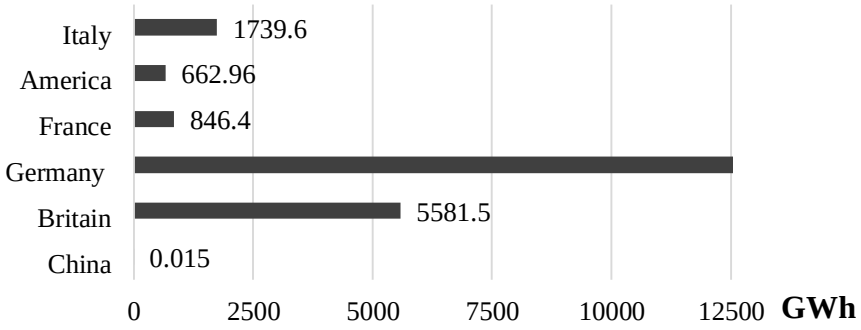
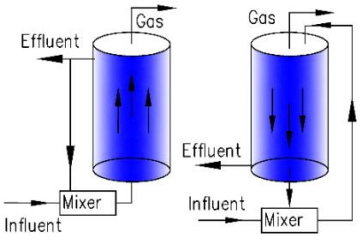
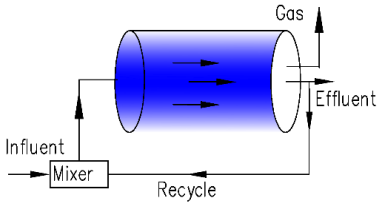
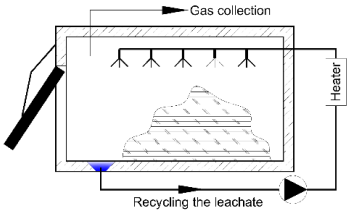


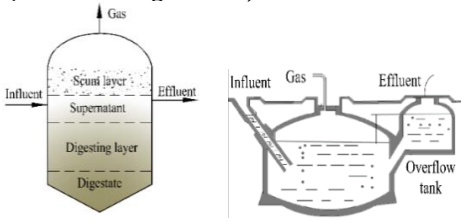
Fig. S3. Biogas power generation in various countries by 2014, adopted from Deng et al. [3].

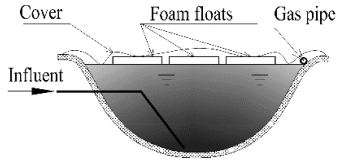
Table S1. Description of the Principles of Anaerobic Solid-State Reactors

Reactor	Description
a) Dry vertical plug-flow reactor 	The dry vertical plug-flow reactor resembles a big cylindrical tank, where the waste stream (TS = 20-35%) is fed at the bottom or top and flows out of the other. In case the waste stream is blended with the inoculum, it is not necessary to do the mixing of the substrate inside the reactor. The reactor is often heated to maintain a mesophilic or thermophilic environment. Operation mode: continuous
b) Dry horizontal plug-flow reactor 	The dry horizontal plug-flow reactor resembles a long tunnel or a rectangular tank with an air-tight cover. The waste stream (TS = 20-35%) is blended with the inoculum and fed to the reactor at one end of the tank, then an agitator or rotor pushes the substrate down to the other end and flows out. The reactor is often heated to maintain a mesophilic or thermophilic environment. Operation mode: continuous
c) Dry batch reactor 	The batch reactor is loaded with fresh materials (TS of 30-40%), discharged after finishing digestion and then filled with a new batch. The continuous recirculation of the leachate allows the inoculums, and substrates to be diffuse in a high humidity environment. The temperature in the reactor is also controlled to accelerate the digestion steps.

Adapted from Abbasi et al. [4], Kayhanian et al. [5], and Vandevivere et al. [6]

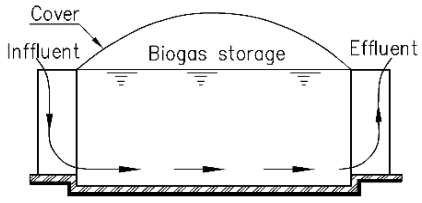
Table S2. Description of the Principles of Anaerobic Wet Reactors

Reactor	Description
Suspended growth reactor	
a) Low rate digester b) Household size  c) Lagoon digester	The cover lagoon, fixed dome, and the floating dome have the same behavior (shown in the next section). In general, they are unmixed and un-heated reactors employing suspended/flocculating anaerobic biomass with HRT in the range of 20-50 d and average SRTs of 50 to 100 days. They are designed for a total chemical oxygen demand (COD) loading less than 2 kg/m^3/d. The effectiveness of the reactor is depended on the ambient temperature.



Operation mode: batch, continuous, or semi-continuous

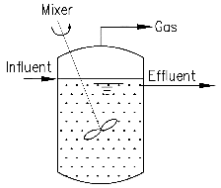
d) The wet plug-flow (WPF) reactor



The wet plug-flow reactor resembles a rectangular tank with an air-tight cover. The waste stream (TS = 11-13%) is fed to the reactor at one end of the tank, the new substrate slowly pushes the older substrate down the tank and flows out at the other end. The tanks may be heated to maintain a mesophilic or thermophilic environment, often using recovered heat from the biogas burner. The hydraulic retention time is 15-20 d.

Operation mode: Semi-continuous, continuous

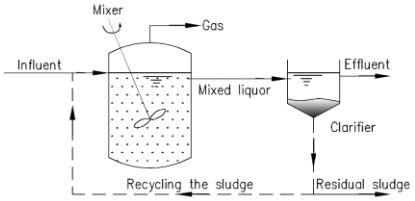
e) Completely Mixed reactor (CMR)



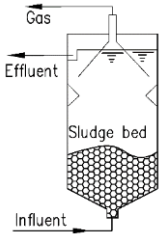
A completely mixed reactor employs suspended/flocculating anaerobic biomass. This reactor can operate with the batch mode or continuous mode. With TS in the range 10-15%, the reactor detention time equals the SRT. With lower TS values, the biomass gets washed away along with the effluent. Therefore, to keep high biomass in the reactor, it is collected in a settling tank and returned to the reactor. This action leads to the HRT being shorter than the SRT.

Application: for the complete AD process or every digestion step.

f) Anaerobic contact process (AC)



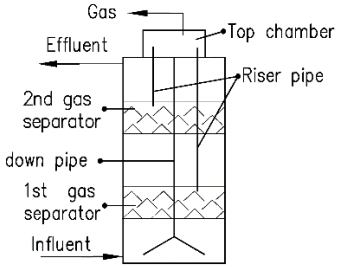
g) Upflow anaerobic sludge blanket (UASB)



The waste stream enters the reactor from the bottom and flows upward. Therefore, the microorganisms in the sludge layer at the bottom contact and degrade the organic matter in the waste stream without the mixing process. A gas-liquid-solid separator at the top separates sludge from the effluent and collects biogas. Conditions: TS < 3%, pH = 6.8-7.8, COD > 400 mg/L, T = 18-35^{o}C, velocity V = 0.2-1 m/h, SRTs = 20-30 d, OLR = 0.4-3.6 kg-COD/m^3/d.

Operation mode: Continuous

h) Internal circulation (IC)

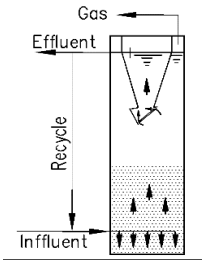


An IC is a UASB reactor equipped with two gas separator as shown in the picture. An internal circulation is created continuously inside the reactor by gas bubble flow. The recirculation provides a good mixing and very efficient reactor operation. Conditions: TS < 1%, COD > 650 mg/l, OLR 20-35 kg-COD/m^3/d, 0.35 m^3-gas/kg-VS, V_{bottom} = 10-30 m/h, V_{top} = 4-8 m/h, and high/diameter = 3-6.

Operation mode: Continuous

i) Expanded granular sludge bed (EGSB)

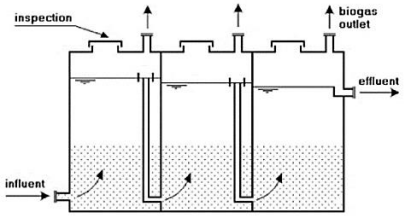
The EGSB reactor mimics the behaviors of the UASB reactor but



with much higher upflow velocity and recirculation of the effluent. This results in the fact that only granular-type of sludge is retained and maintained expanded in the reactor. Conditions: pH ~ 7, T > 10^{o}C , V = 4-10 m/h, OLR = 5-20 kg-COD/m^{3}/d. COD = 1-2 g/L. Application for low strength soluble materials

Operation mode: Continuous

k) Anaerobic baffled (AB) reactor

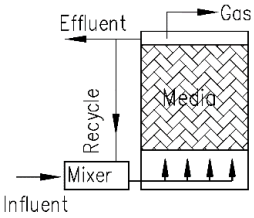


The baffled reactor has a series of multiple chambers. In this reactor, each chamber is equipped with vertical baffles that force the liquid to make a sequential down-flow and up-flow movement, to guarantee a larger contact of the substrates with the microorganism that accumulate at the bottom of the chambers. Application for TS = 2-10%, T = 13-37^{o}C, SRTs>30 days, HRT = 6-24 h, OLR up to 5-10 kg-COD/m^{3}/d, COD of 0.45-1.0 g/L

Operation mode: Semi-continuous, continuous

Attached growth wet reactor

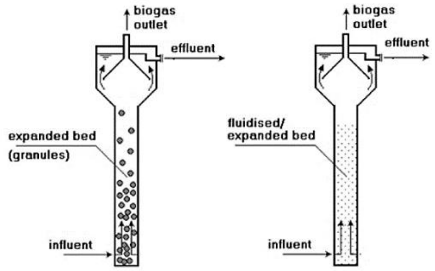
l) Anaerobic fixed bed (AFB)



AFB reactor, also called anaerobic filter reactor, is an unmixed reactor employing anaerobic biofilm. The feedstock entered into the reactor can flow through submerged supporting materials. The organic matter is degraded by the active microorganism that is attached to the surface of the supporting materials. Conditions: TS < 5%, T = 25-38^{o}C, V = 2m/h, SRT = 1-10 d, OLR up to 16 kg-COD/m^{3}/d and packing media = 50-70% reactor volume.

Operation: often in the continuous mode.

m) Fluidized bed (FB), expanded bed (EB)



These reactors employ the small size (0.10 to 0.30 mm) inert particles where anaerobes attach to their surface. The particles are kept in suspension and mixed by a high upward velocity. The high velocity leads to a fluidized bed with 25 to 300% bed expansion and the expanded fluidized bed refers to operation at lower velocity with 15 to 25% bed expansion. Conditions: pH ~ 7, T = 20-35^{o}C, V = 10-30 m/h, and OLR of 10 to 50 kg/m^{3}/d.

Operation mode: continuous

Adapted from Burton et al. [7], Chernicharo and Augusto [8], Abbasi et al. [4], Technologien and Wirtschaftsberatung [9], and Wang et al. [10].

Table S3. Configurations of a Three-Stage System

Reactor	Temperature	Feeding mode	Total solid (%)	Type of reactor
First-reactor	Psychrophilic	Batch	Low	CSTR
	Mesophilic	Semi-continuous	High	Plug-flow reactor
		Continuous		

Second-reactor	Mesophilic Thermophilic	Continuous	Low	CSTR, UASB
Third-reactor	Mesophilic Thermophilic	Continuous	Low	CSTR, AFB, UASB, EGSB, EB, FB.

References

1. Zhang C, Su H, Baeyens J, Tan T. Reviewing the anaerobic digestion of food waste for biogas production. *Renew. Sust. Energ. Rev*. 2014;38:383-392.

2. Mata-Alvarez J. Biomethanization of the organic fraction of municipal solid wastes. Fundamentals of the anaerobic digestion process. Vol. 12, London, UK: IWA publishing; 2003.

3. Deng Y, Xu J, Liu Y, Mancl K. Biogas as a sustainable energy source in China: regional development strategy application and decision making. *Renew. Sust. Energ. Rev*. 2014;35:294-303.

4. Abbasi T, Tauseef S, Abbasi SA. Biogas energy. Vol. 2, New york: Springer Science & Business Media; 2011.

5. Kayhanian M, Tchobanoglous G, Brown RC. Biomass conversion processes for energy recovery. In: D. Goswami, Yogi and K. Frank, eds. Handbook of energy efficiency and renewable energy. Florida, USA: CRC Press; 2007. p. 22.1-22.67.

6. Vandevivere P, De Baere L, Verstraete W. Types of anaerobic digester for solid wastes. In: J. Mata-Alvarez, eds. Biomethanization of the organic fraction of municipal solid wastes. London, UK: IWA Publishing; 2003. p. 111-140.

7. Burton FL, Stensel HD, Tchobanoglous G. Wastewater engineering: treatment and Resource recovery. 5th ed. Vol., New york: McGraw-Hill; 2014.

8. Chernicharo dL, Augusto C. Anaerobic reactors. ed. BiologicalWastewater Treatment Series, ed. Vol. 4, London: IWA publishing; 2007.

9. Technologien N, Wirtschaftsberatung B-u. Anaerobic treatment of municipal wastewater in UASB-reactors: Frankfurt, Germany. 2001.

10. Wang Y, Liu X, Zhuang W, Zhou J, Wang J. Advance: IC reactor for high strength industrial wastewater treatment and biogas production. In: Materials for Renewable Energy & Environment (ICMREE), 2011 International Conference on. 2011; IEEE; p. 423-427.