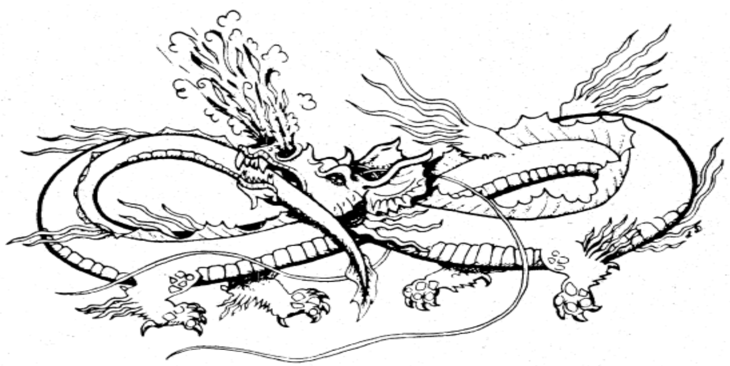
The Why and Wherefore of Biogas Systems



The Domestication of Anaerobic Microbes

NATURAL GAS WITHOUT FRACKING

Dragon Husbandry in Regenerative Agriculture

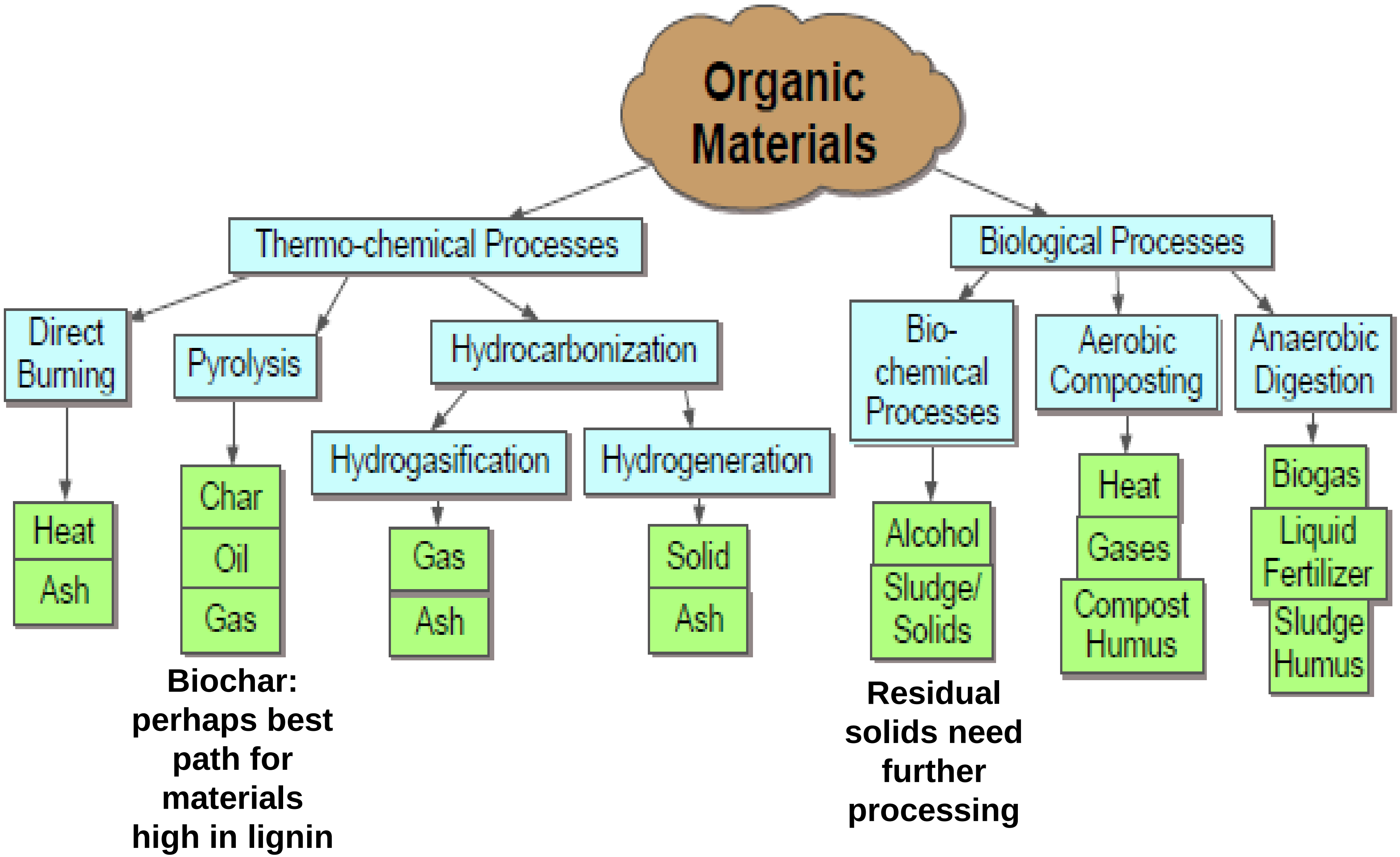
Riding the Dragon since 1974

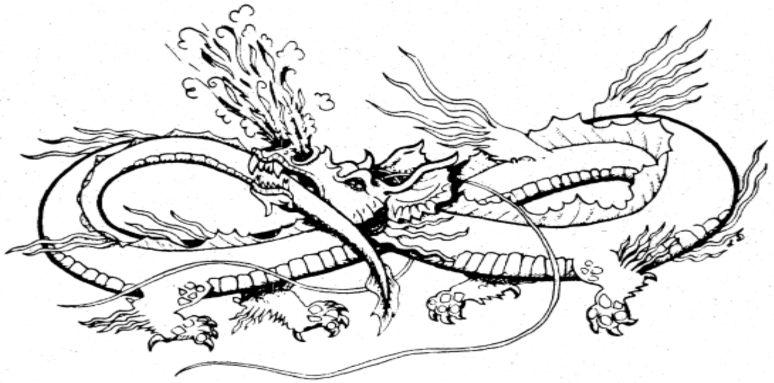
Omega-Alpha Recycling Systems

www.omega-alpharecycling.com

bhanomalous7@gmail.com

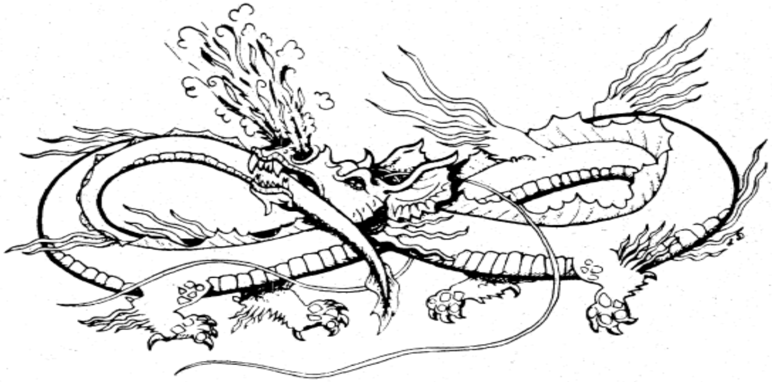
Options for Utilization of Organic Materials and Residues





Anaerobic Microbes in Nature:

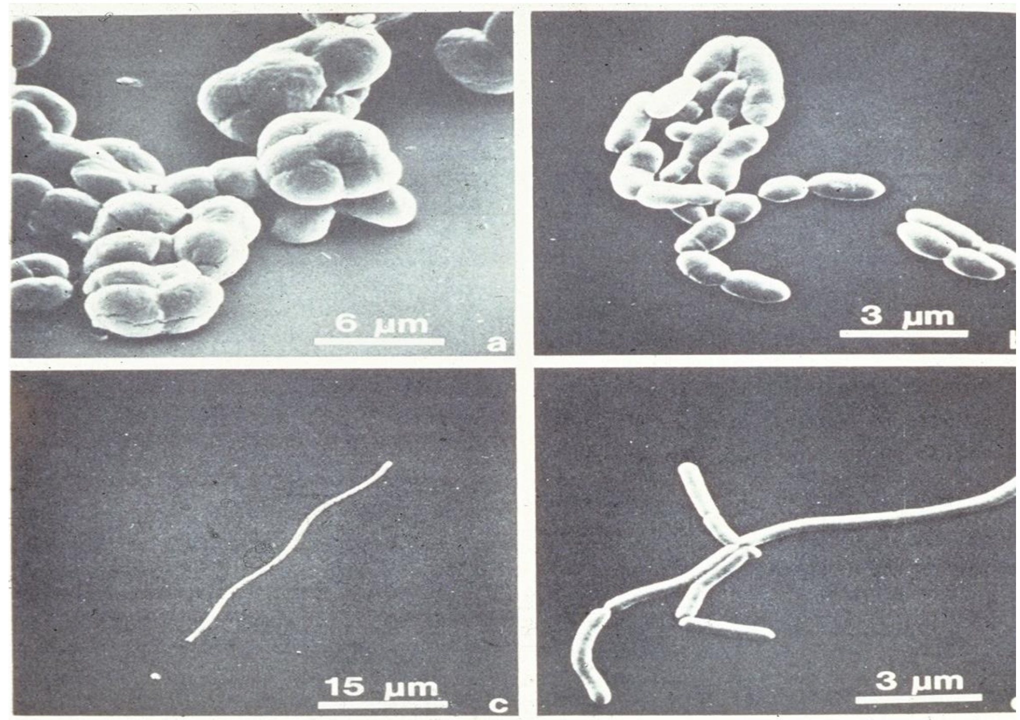
And some rationale for establishing more symbiotic, external, human being--anaerobic microbe relations

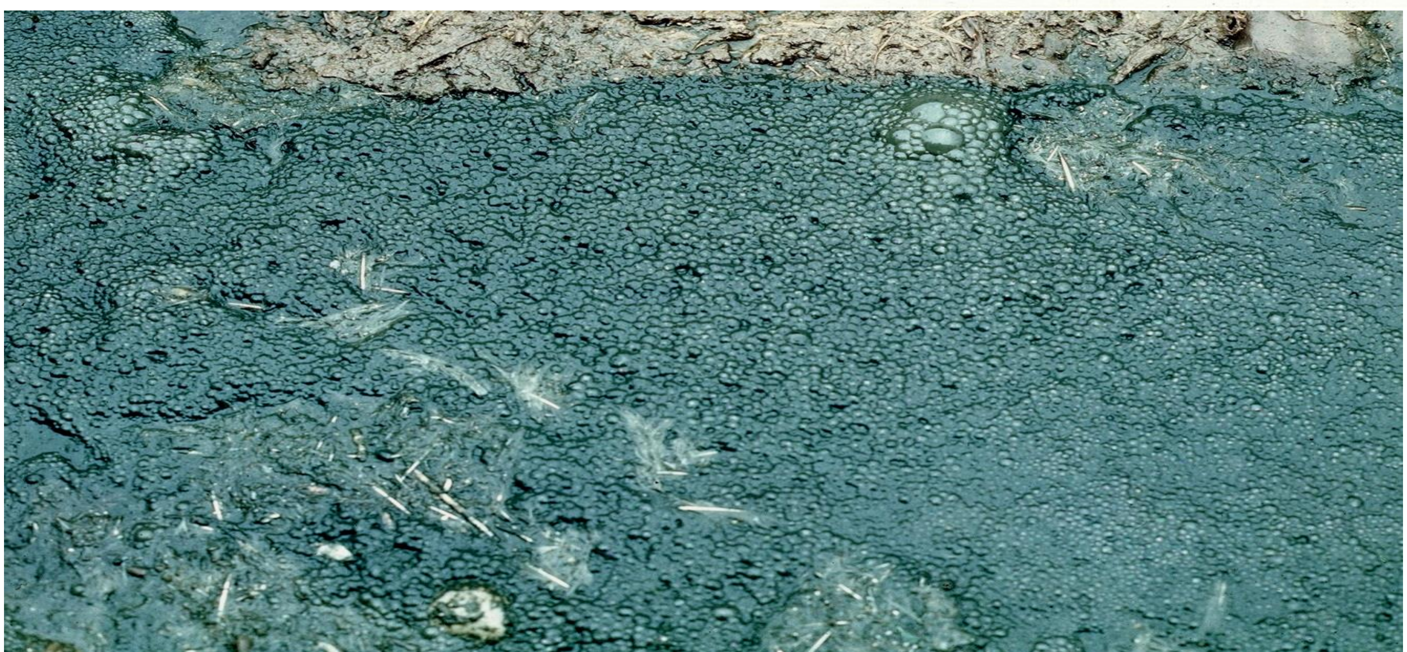


Anaerobic microbes

A few of the millions of species

The earliest life on earth

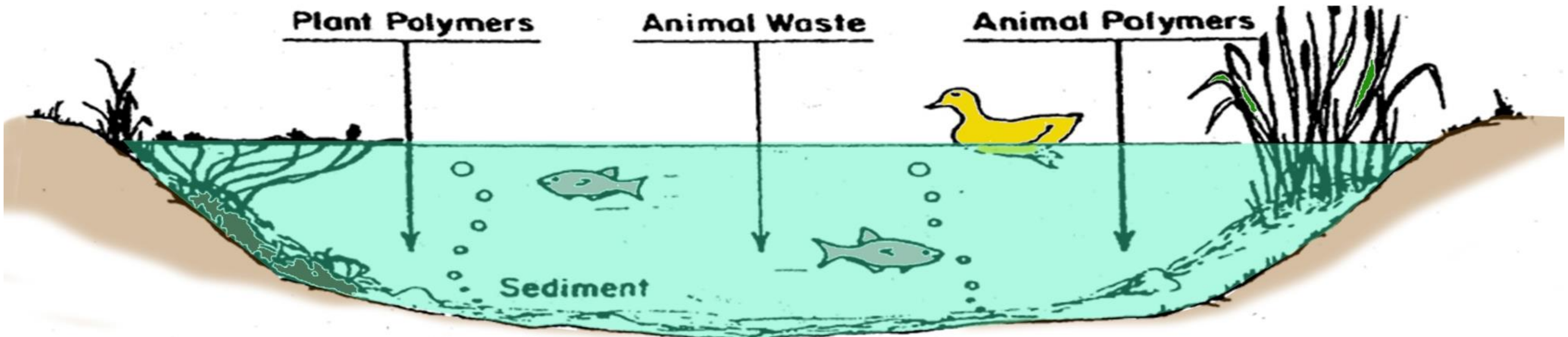




Gas bubbling out of swine manure tank, China, 1987

Anaerobes in Nature – Oxygen-Starved Environments –

Pond, Lake, Sea and Ocean Bottoms, Deep Soils, Permafrost, and the Guts of Larger Animals

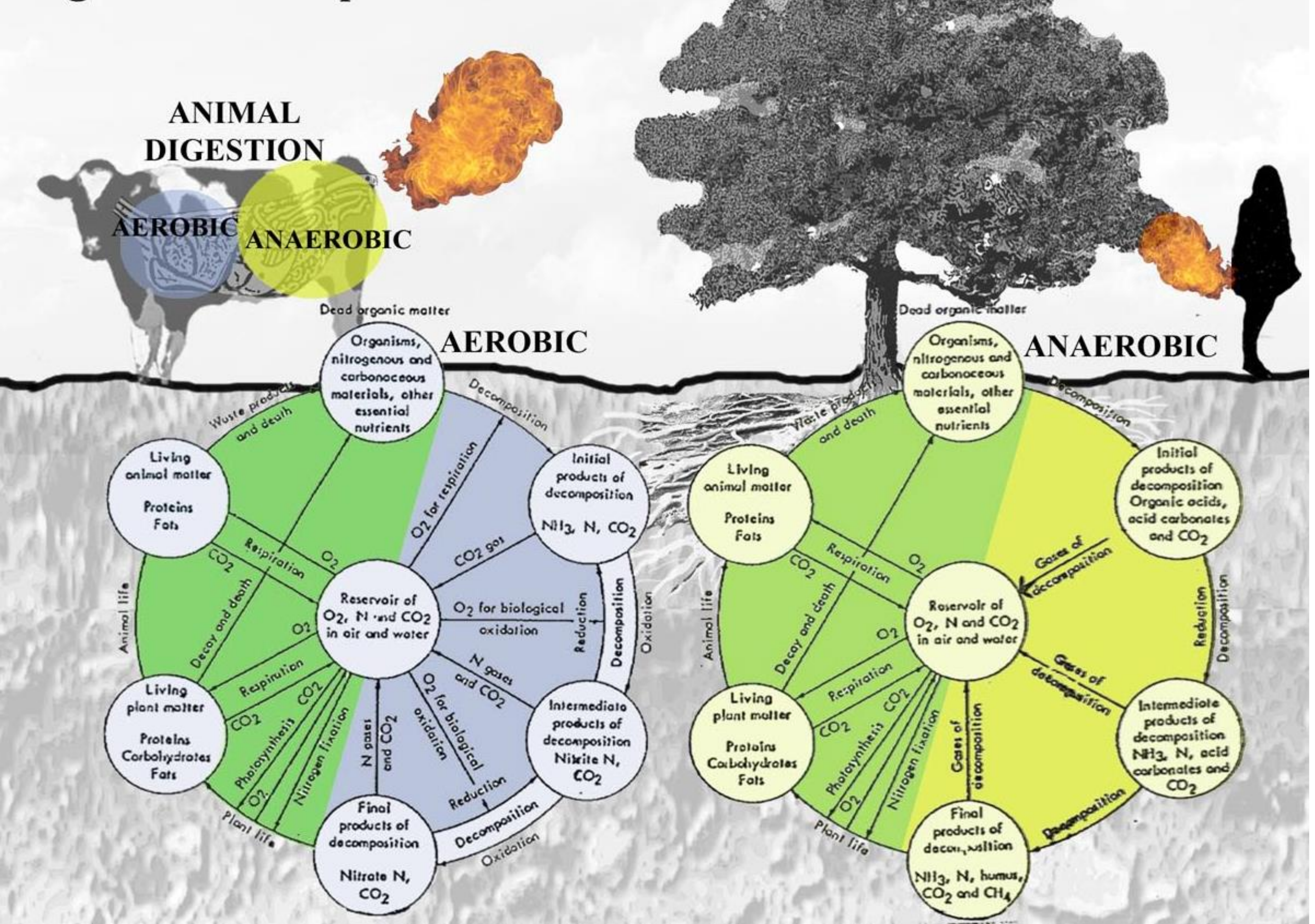


Microbial Life on Earth comprises:

- 60 % of all Biomass
- 350-550 Pg Carbon (60-100 % more than all plants)
- 85-130 Pg Nitrogen (10 X more than plants)
- 4-14 Pg Phosphorus (10 X more than plants)
- They communicate within their own species and with other species through specific chemical excretions.

Cells in the human body – 10^14, 100 trillion
Microbes in and on the body – 10^15, 1 quadrillion

Organic Decomposition in Nature



COMPOSTING VIS-A'-VIS DIGESTION

	AEROBIC		ANAEROBIC
Moisture Levels	40-60%		99-50% <75%=slow activity
Oxygen as O2	Large amounts necessary		Fatal
Carbon Dioxide	All Carbon lost in this form		30-40% of biogas is C02
Nitrogen	Loss up to 50% usually 25% N_2 or NH_2 without close control; nitrates dominate in final product		Little control necessary for recovery of essentially all original; amonia dominate in final product
Particle Size		Smaller size=quicker process	
Carbon Reduction		In controlled conditions, loss of dry-weight C can be over 60% of that in original material	
C/N Ratio		20-35:1-Optimum. Biologically decomposable quantities of C/ N are determined by checking losses after process occurs	
Time Required		Days or less for dilute organic water digestion. In controlled conditions weeks or months. Complete decoposition takes years.	
pH		Final products are neutral to slightly alkaline	
Photosynthetic Energy	Largely released as heat		Largely contained in methane produced
Pathogen Destruction	Complete destruction if all materials reach >55 degrees C for a few hours		Very significant, a subsequent composting of sludge is necessary for total destruction (especially Ascaris eggs)
Other Nutrients	Potential leaching of soluable forms in uncovered piles		Well maintained

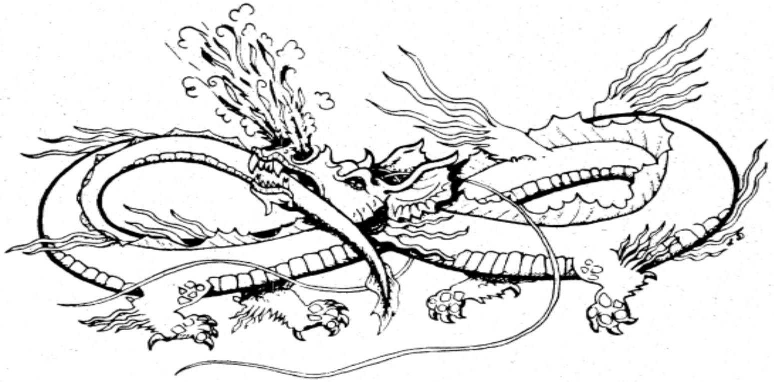
BENEFITS OF BIOGAS SYSTEMS

- **NUTRIENT CONSERVATION**
  ALL nutrients going into a digester are available in the effluents (except for a small amount of sulfur released as H_2S, and some N_2 if digester feed is unbalanced), thus providing a full spectrum of plant nutrients and reducing or eliminating the need for chemical fertilizer input.
- **SOIL REGENERATION**
  Organic carbon compounds in the effluents increase the humic content of agricultural soils.
- **SANITATION**
  When allowed to go toward completion, anaerobic digestion results in total destruction of most disease vectors which may have been present in the feed materials; nearly total destruction of most of those remaining; and very significant destruction of the most recalcitrant (including ascaris and other eggs). Also, the digestion process does not result in any new pathogen vectors.
- **PROVISION OF NATURAL GAS**
  With minor adjustments, biogas (generally 65 % CH_4, 35 % CO_2, and traces of others) can be used in any way fossil gas is used.
- **REDUCTION OF INDOOR AIR POLLUTION AND RESPIRATORY PROBLEMS**
  Pollutant emissions from combustion of biogas are similar to those from burning fossil gas. When biogas is used to replace biomass or coal as a cooking fuel, indoor air pollution and related health problems are greatly reduced.
- **ODOR CONTROL** - Volatile solids (what we smell) are largely consumed by digestion.
- **FLY AND RODENT CONTROL** – Not attracted to digester effluents.
- **WEED CONTROL** – Reduction of viability.

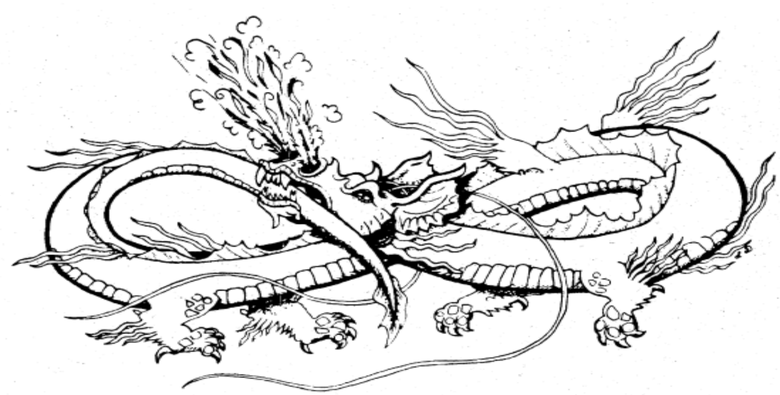
The most pollution-free option for sustainable utilization of biomass energy!

The means to most closely approach the ideal of carbon neutrality!

NATURAL GAS WITHOUT FRACKING



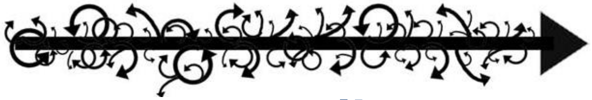
Prevailing and Alternative Myths: Social and Biospheric Impacts



A FEW PERSPECTIVES

LINEAR

Blindered

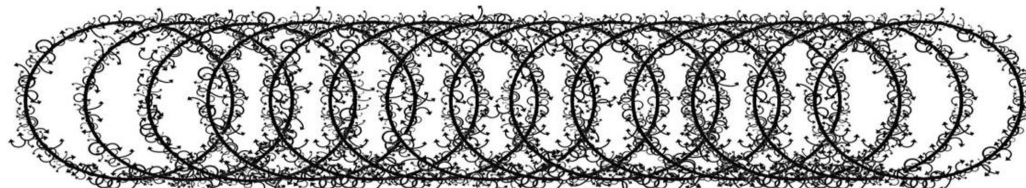


In reality

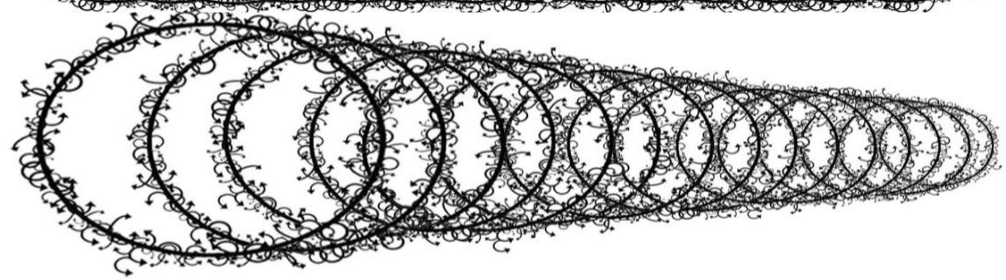
CYCLICAL

CYCLICAL OVER TIME

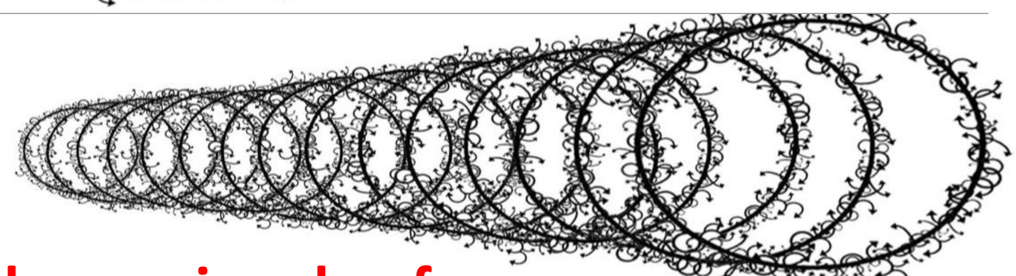
Status quo



Decreasing - Degenerative



Increasing - Regenerative



Proposition: Concern for the semi-cycle of return is a key to increasing life and its diversity.

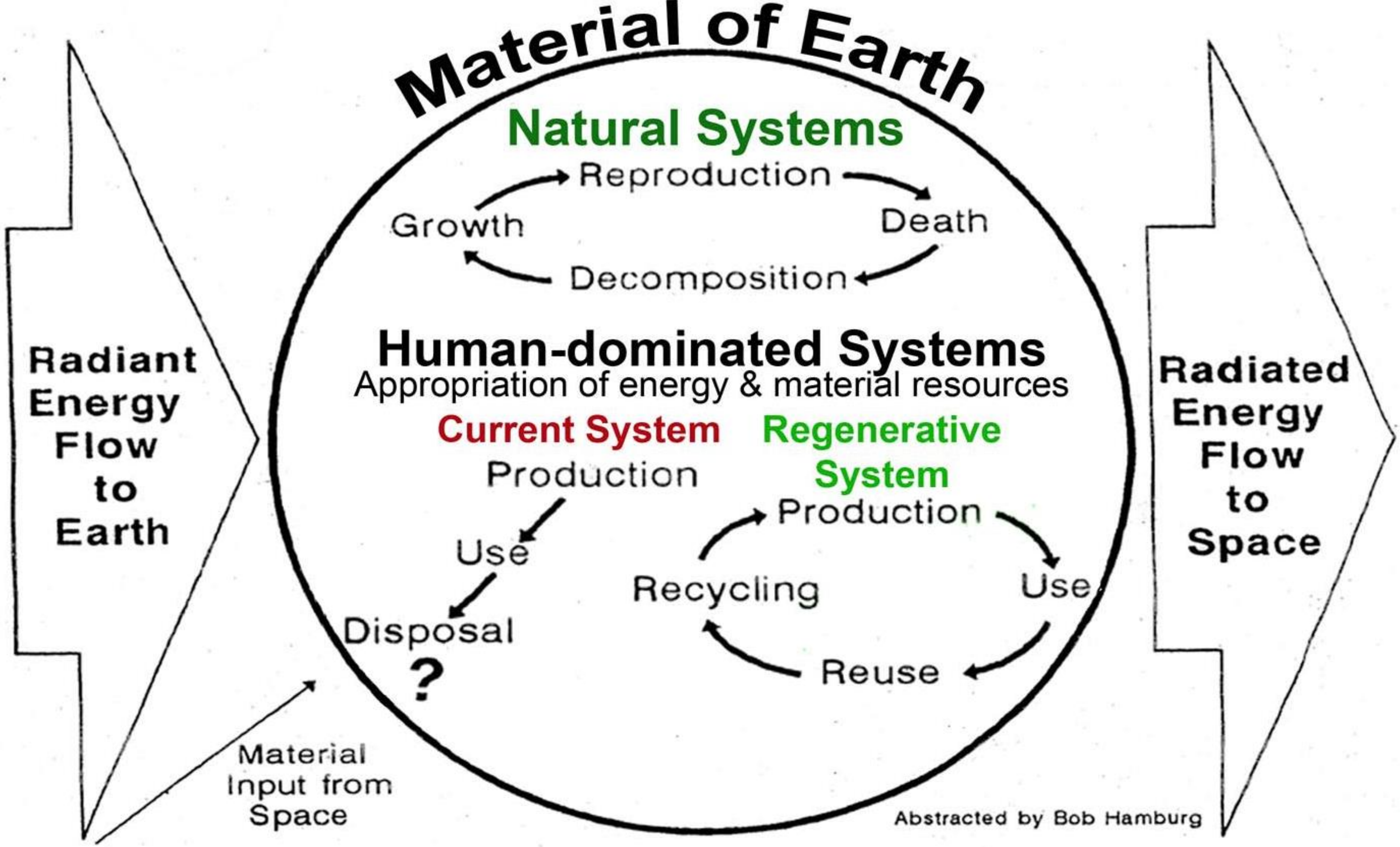
CONTRASTING MYTHOLOGIES

STATUS QUO
REGENERATIVE ALTERNATIVE

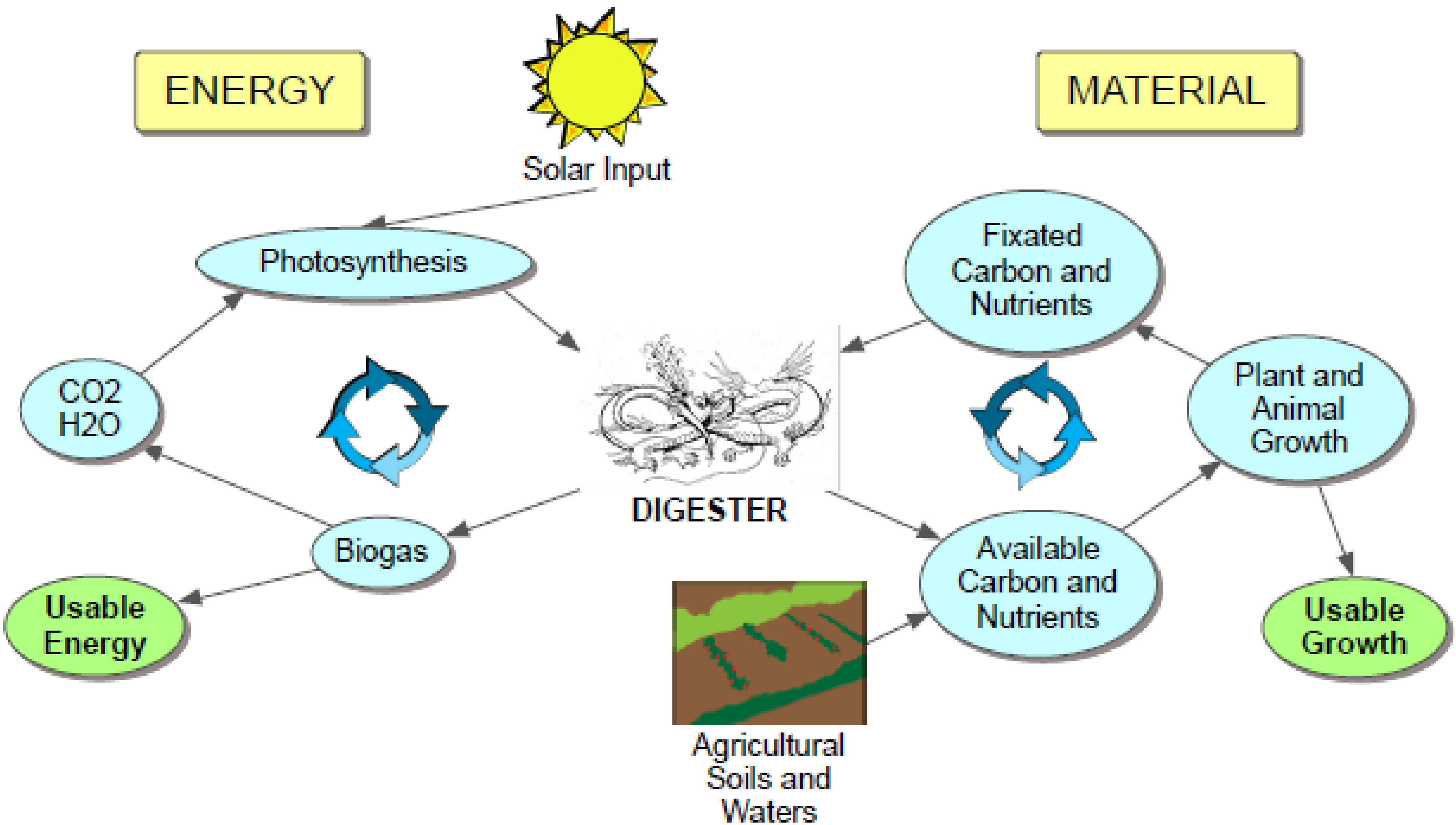
Status Quo	Regenerative Alternative
Linearity	Cyclicality
Exploitation	Regeneration
Competition	Cooperation
Quantitative Growth	Qualitative Development
Wastes	Resources
Disposal	Management/Reuse
Rugged Individualism	Resilient Communality
Centralization	Localization
Economic Theory	Biophysical Reality
Reductionism	Integration/Synthesis
Endless Physical Growth	Physical Limits
Fossil Fuels	Renewable Energies
Human Dominance	Human Symbiosis
High Technology	High Ecology/Biology
Human Exceptionalism	Gaian Cooperation
Parasitism	Symbiosis
American Exceptionalism	Human Community

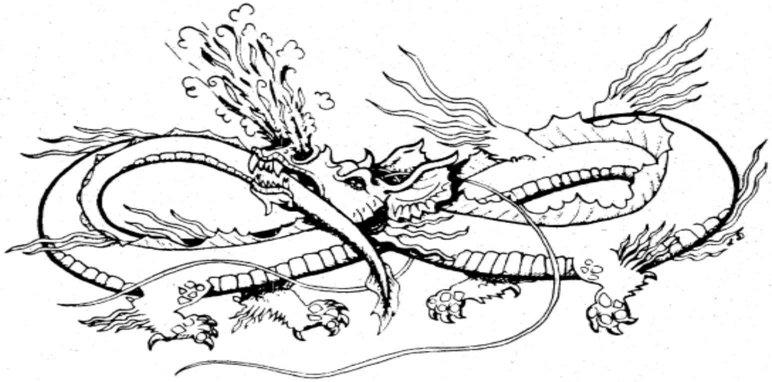
See also: http://thoughtmaybe.com/life-at-the-end-of-empire/

The Basic Background for Resource and "Waste" Management

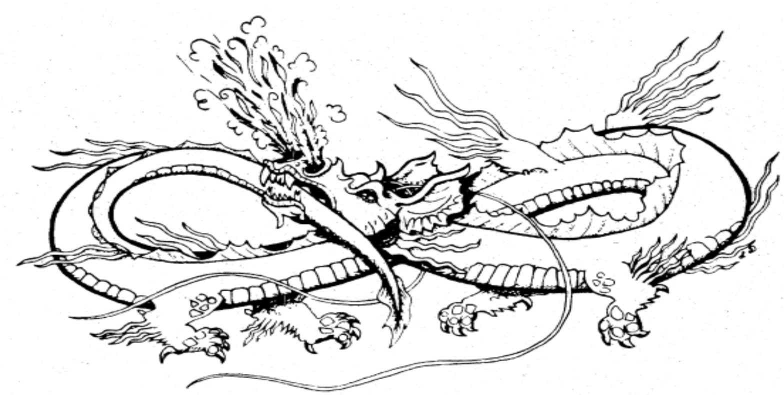


ANAEROBIC MICROBES' MEDIATION BETWEEN SOLAR ENERGY AND EARTHLY MATERIAL





SOIL AND AGRICULTURAL SYSTEMS



Soil Organic Matter ~Carbon ~Energy

Increase in soil OM results in:

Darker color;

Increased water infiltration, holding capacity and content;

Increased aeration and permeability;

Improved soil structure;

Increased cation exchange capacity and nutrient availability;

Increased pH buffering;

Increased soil biota;

Decreased soil temperature; Increase metabolic activity.

Organic materials (OM) in the soil can be seen as being composed of relatively stable humus and biologically active materials which are constantly recycled through a myriad of micro- and macro-scopic soil organisms. The importance of this material to agricultural soils relates to biological, chemical and physiological qualities developed through interaction of OM and soil organisms with soil minerals. While these interactions may vary, an increase in the level of soil organic material generally includes the following effects (largely after Brady, 1984, and Parr, 1983):

— Soil color is darkened;

— Water infiltration, holding capacity and content are all increased. Concomitantly, drought susceptibility, erosion and resulting sedimentation, and nutrient runoff and leaching resulting in eutrification of water bodies are all decreased. A change in soil OM of 1% changes the erodability factor (K) in the Universal Soil Loss Equation by 10% as well as improving the structural index and the permeability class (Papendick, 1984). Livestock manure applied at a rate of 16 t/a to Iowa corn land with a slope of 9% reduced erosion from 22.1 to 4.7 t/a (Pimentel, 1976);

— Aeration and permeability [pore size] are increased and bulk density is decreased. Summerfeldt (1985) found that bulk density decreased at a rate of .002 Mg/cu m per megagram of manure applied /ha/yr;

— Soil structure is improved through encouragement of granulation and aggregation while crusting, plasticity and cohesion are reduced;

— Plant nutrients are more available [once decomposition is complete]. Cation exchange capacity is increased—OM colloids having 2-30 times the capacity of mineral colloids by weight and accounting for 30-90% of the adsorbing capacity of mineral soils (Brady, 1984). More nutrients are held in organic forms and more mineral elements are released by the action of humic acids;

— The pH buffering capacity of the soil is increased (Arnott, 1982);

— Soil biota increase in both number and variety, thus offering a greater opportunity for biological control of soil-borne pathogens (Lumsden, 1983); and,

— Due largely to increased moisture retention, soil temperatures tend to decrease. This decrease is somewhat mitigated by increased absorption of solar energy thru darkening color and increased metabolic activity in the soil.

While the inherent capability of soil to produce crops is closely related to the level of OM [and nitrogen] in the soil (Brady, 1984), this level tends to decrease when the land is used for agricultural activity—and the more intensive the cultivation, the faster the rate of OM loss.

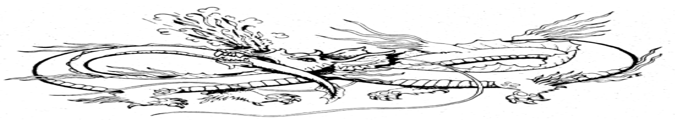
AGRI-INDUSTRY VIS-A'-VIS AGRICULTURE

Examples -- Conventional Farming, Monoculture, Green Revolution		Examples -- Organic Farming, Agro-forestry PermaCulture
Plant and animal growth well over 90% dependent on solar energy	*	Plant and animal growth well over 90% dependent on solar energy
Emphasis on short-term productivity and financial profitability		Emphasis on sustainability, long-term productivity and adequate profitability
Quantity, transportability, appearance and minimum costs are often emphasized over taste and nutritional value		Quality in taste, variety and nutritional value are often valued over quantity, appearance and minimal costs
Highly centralized production and distribution systems; no contact among producers and consumers		Decentralized, local production and distribution systems; striving for much interaction among producers and consumers
High dependence on extensive transportation systems -- worldwide and national		Dependence of local transportation systems
Soil mainly a mere matrix for root growth; the soil on a speed trip		Soil as a living organism -- Feed the soil and the soil feeds you
Highly dependent upon fossil fuels for production, transportation, and chemical inputs -- most often at very large scales		Emphasis on reduction of fossil fuel dependency for all inputs -- generally, much smaller-scale equipment
Highly dependent upon fossil fuels for chemical fertilizers, and highly toxic chemical pesticides, herbicides and fungicides; aims at eradication of all but the chosen species		Reliance on natural and organic fertilizers; reliance on rotations and largely biological and mechanical pest control; emphasis on recognition and increase in populations of beneficial insects and other organisms; aims at control rather than eradication
Organic residues and run-off largely a problem for disposal rather than resources for the future -- largely associated with over-centralization		Emphasis on organic materials recycling and holding moisture and nutrients in the soil; maintaining and increasing soil organic matter
Reduce human labor and input largely through large-scale mechanization and total eradication of all competitors		Reduce human labor through mindfullness and more selective activities at smaller-scales; more knowledge and thought-based; aims at reliance on beneficial insects and other organisms to accomplish necessary tasks
Trans-species genetic engineering		Intra-species, Mendelian and non-Mendelian genetic manipulation
Emphasis on broad monoculture of genetically identical crops and animals		Emphasis on maintaining broad genetic heretige of plants and animals
Huge, highly concentrated, confined livestock raising		Striving toward humane, more free-roaming livestock raising
Huge corporate integration and competition; maximization of profit through externalization of costs -- commonize costs and privatize profit; The CC-PP Game		More small business and co-operative integration with emphasis more on cooperation; recognition of externalized costs and striving to internalize

A PERMACULTURE FAIR-SHARE VIEW OF DRAGON HUSBANDRY

WE PROVIDE

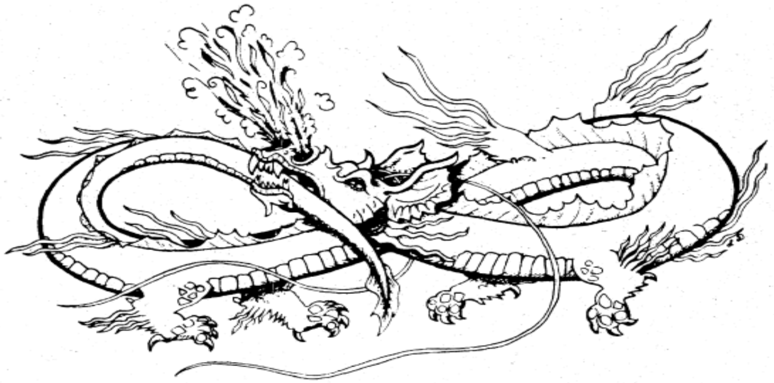
- A "BODY" IN WHICH TO EXIST
- A WARM PLACE IN WHICH TO LIVE
- APPROPRIATE WATERING
- APPROPRIATE FEEDING
- ADEQUATE CARE
- RESIDUALS REMOVAL AND RECYCLING



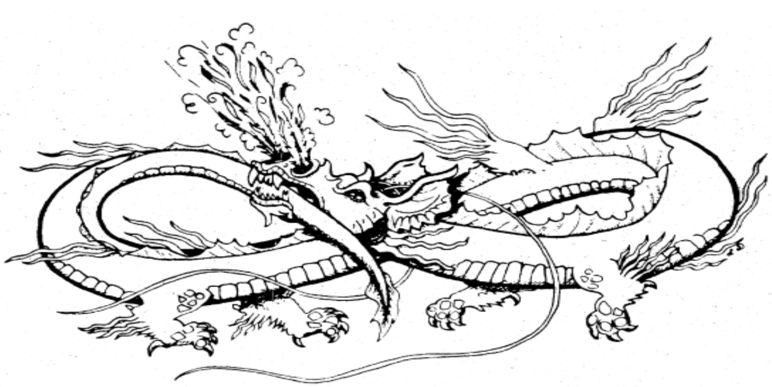
WE GET

* NUTRIENT CONSERVATION
* SOIL REGENERATION
* SANITATION
* PROVISION OF CARBON-NEUTRAL NATURAL GAS
* REDUCTIOON OF INDOOR AIR POLLUTION AND RESPIRATORY PROBLEMS
* ODOR CONTROL
* FLY AND RODENT CONTROL
* WEED CONTROL

PLUS SYMBIOTIC EARTH CARE AND PEOPLE CARE



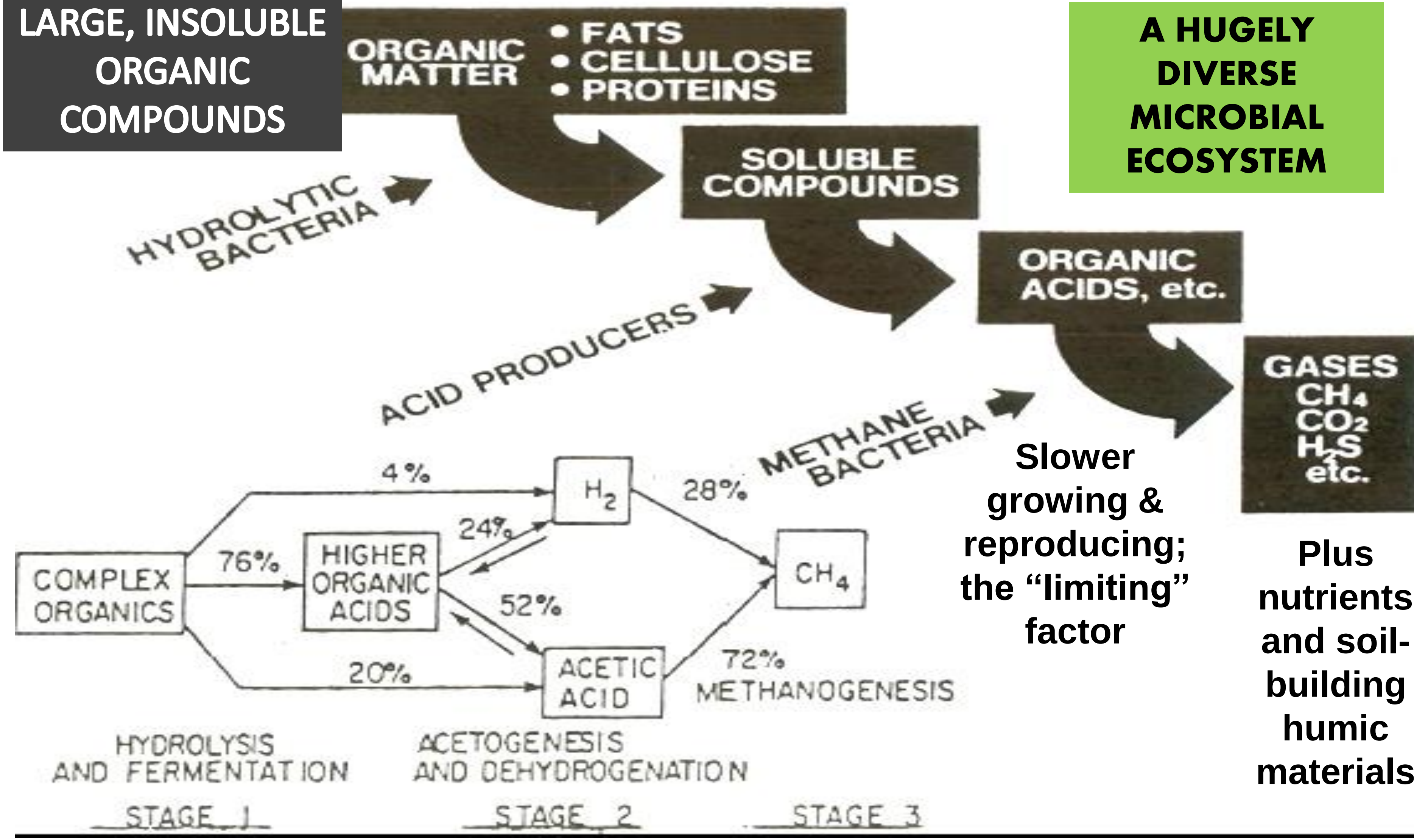
THE BASICS OF ANAEROBIC DIGESTION PROCESSES



The Digestion Process

1st - Mechanical breakdown of larger organic materials -- Best accomplished before digestion – then, within the beast:

LARGE, INSOLUBLE ORGANIC COMPOUNDS

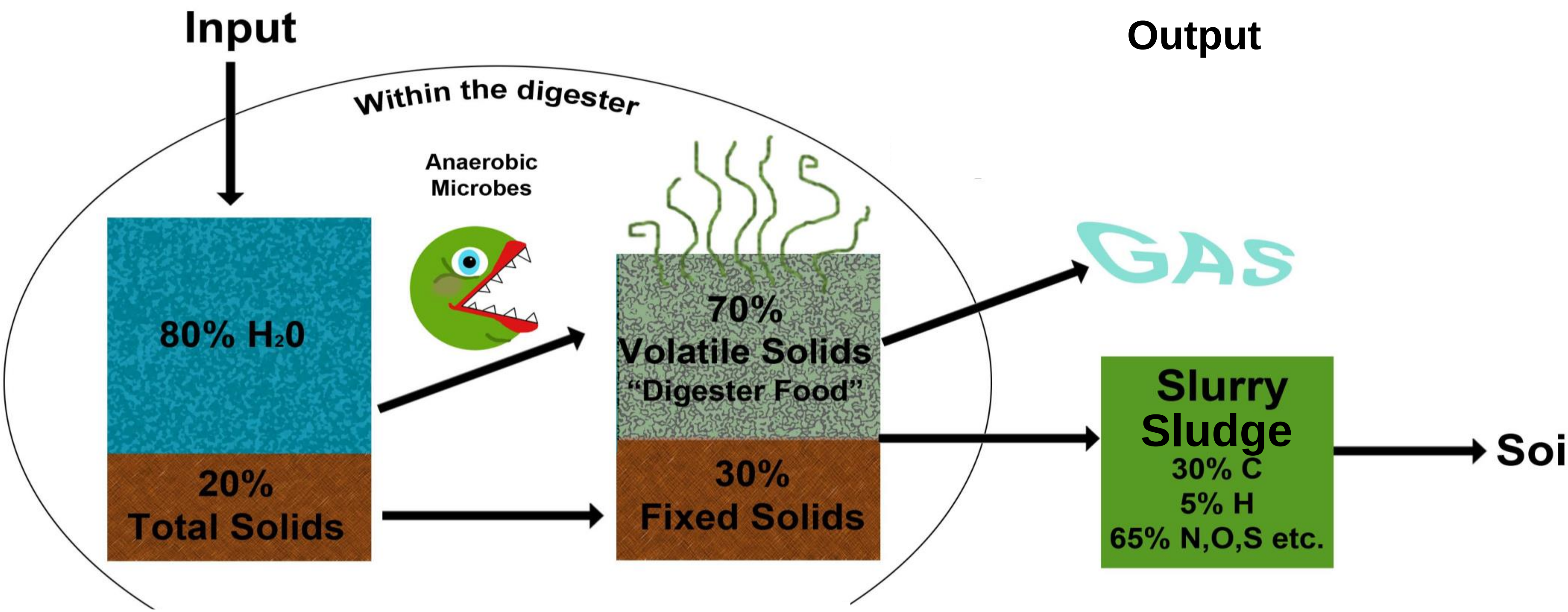


A HUGELY DIVERSE MICROBIAL ECOSYSTEM

Slower growing & reproducing; the "limiting" factor

Plus nutrients and soil-building humic materials

Glossary of “Solids”



Total solids –
all but water.
Generally,
5-15% for simple mesophilic digestion

Fixed solids --
sterilized carbon and other nutrients.

Volatile solids –
give odor; are the “food” for digesters; and include quantities of nutrients.

BASIC BIO-CHEMICAL CONCERNS

(For a much more adequate, working understanding, OARS highly recommends the __Biogas Handbook__ by David House, 2006, available through ***www.completebiogas.com.****)*

__Maintenance of anaerobic conditions__ – Gas tightness; Materials and Construction

__Digester feed composition__ – Total Solids, Volatile Solids and Fixed Solids; Particle size; Manures vav field/kitchen residues; [6-10 % solids for continuous -- much higher % possible for batch systems]; **NOT LIGNIN – i.e. woody residues**;

__Carbon/Nitrogen Ratio (C/N)__ – As with composting, about 20-30 : 1 [but dependent on "digestibility"]

__Temperature__ – Optimums at about 100° F for mesophilic and about 135° F for thermophilic

pH – 6.8—8.5, well-buffered (bicarbonates of soda); [Self-buffering if not abused. If pH begins sinking, slow feeding.]

__Hydraulic Retention Time__ – Time spent in the digester; [Time/temperature/etc. dependent]

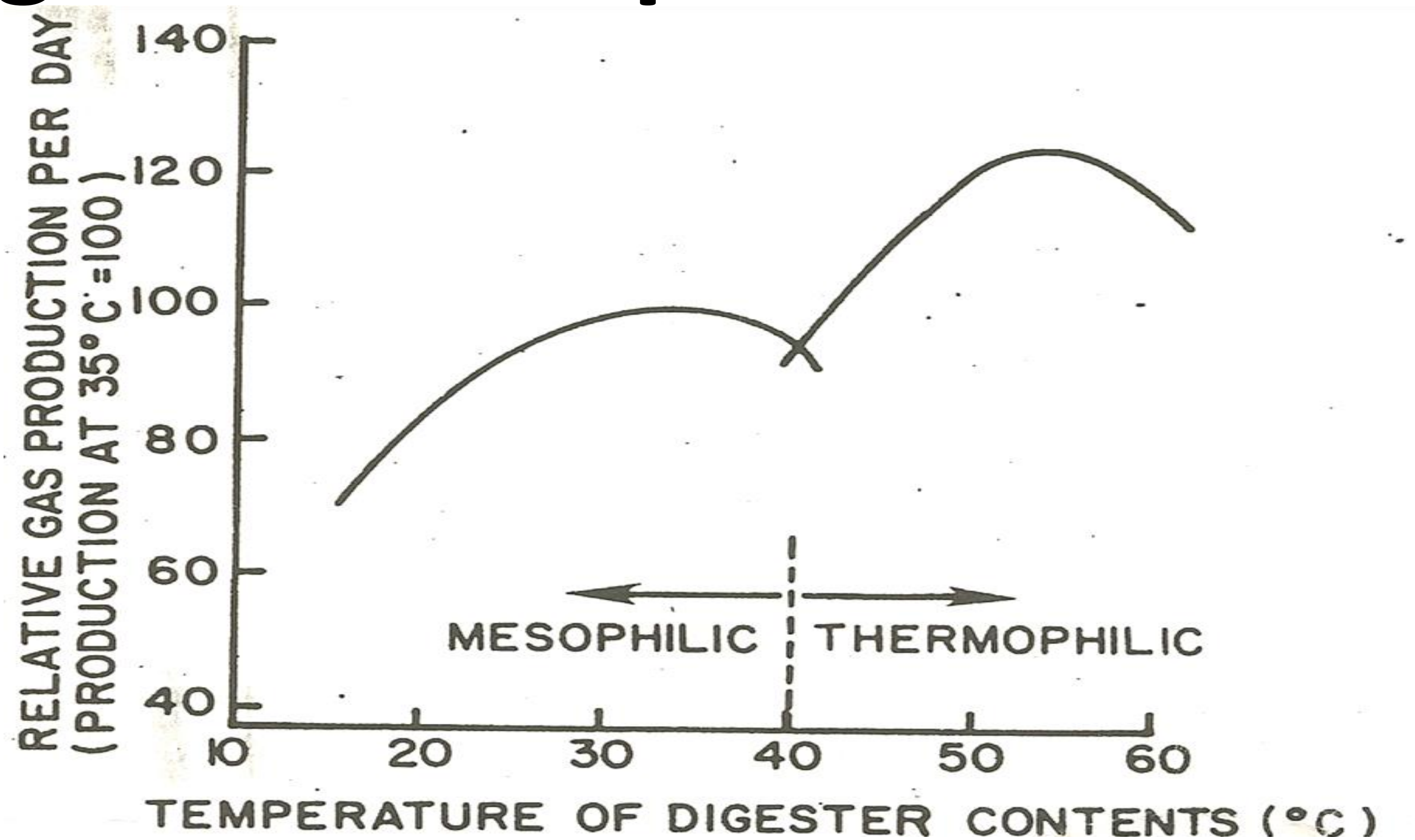
__Loading Rate__ – System and management determined

__Agitation__ – About 5-10% of time: [Gas recirculation provides multiple benefits]

__Toxins to digestion__ – Antibiotics; Pesticides; Herbicides; Heavy metals; NH_3 overload; [Most organics - medicines, drugs(?) decomposed and rendered harmless]

__Sanitation__ – Sterilization vav Sanitation. NOTHING NEW PRODUCED! In 30 days, destruction of all of most, nearly all of most of the rest, and significant percentages of the most recalcitrant. [The closer to optimum, the sooner and more complete]

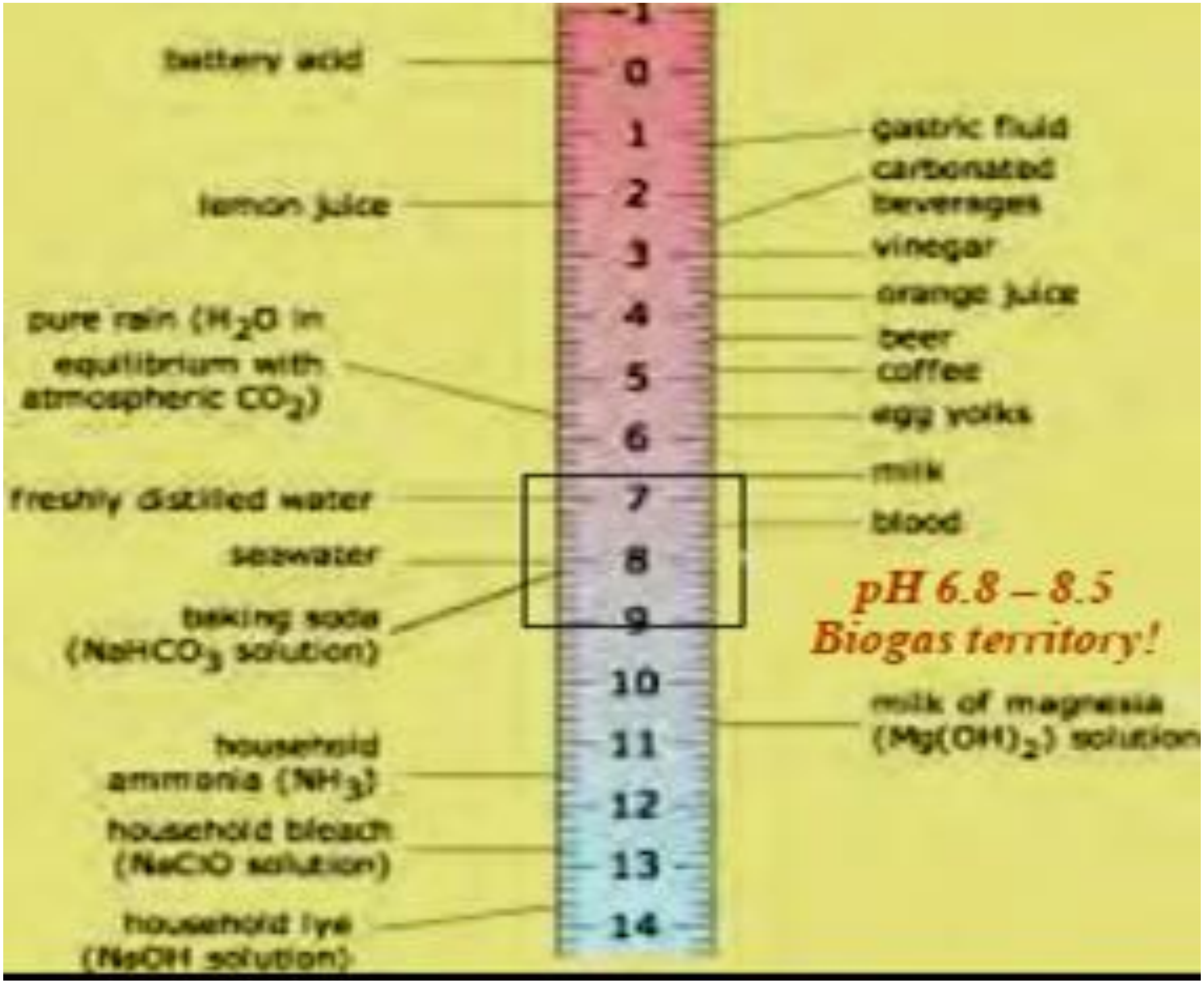
Digestion Temperature Ideals



Mesophilic microbes grow best at moderate temperatures, peaking at about 95-105 degrees F.

Thermophilic microbes grow best at higher temperatures, peaking at around 140 degrees F. Faster digestion but much more “sensitive” to all upsets.

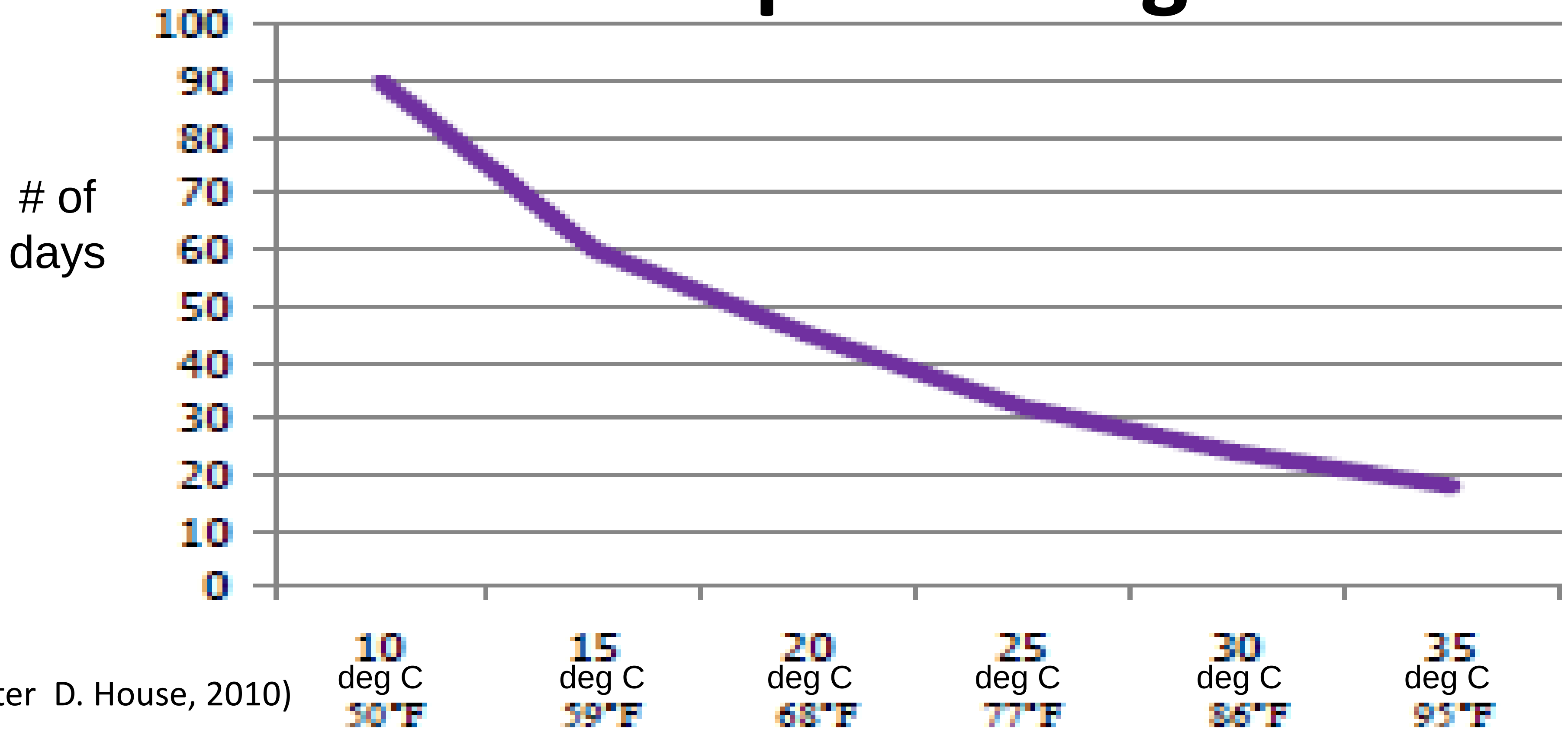
pH Considerations



From D. House, 2010

Hydraulic Retention Time (HRT) = length of time materials remain in the digester

HRT X Temperature -- for equal levels of digestion in the mesophilic range --



(After D. House, 2010)

A brief note on Pathogen Destruction during Digestion

DISEASE ORGANISM	RETENTION TIME	REDUCTION IN VIABLE ORGANISMS	REFERENCES
Schistosome Eggs (winter)	37 days	100%	Van Buren, '76
Schistosome Eggs (summer)	14 days	100%	Van Buren, '76
Hookworm Eggs	30 days	100%	Van Buren, '76
Flat/Tape worm Eggs	70 days	>90%	Van Buren, '76
Dysentery bacillus	30 hours	100%	Van Buren, '76
Paratyphoid bacillus	44 days	100%	Van Buren, '76
Average of Parasite Eggs	?	93.6%	McGarry, '79
Ascarid Eggs	?	61%	McGarry, '79
Spirochetes	31 hours	100%	McGarry, '79
E. coli	?	99.94%	McGarry, '79
Salmonella sp.	2-20 days @ 22-37 °C	82-96%	Barnett, '78
Salmonella typhosa	2-20 days @ 22-37 °C	82-96%	Barnett, '78
Mycobacterium tuberculosis	? @ 30 °C	100%	Barnett, '78
Oscaris lumbricoide	15 days @ 29 °C	90%	Barnett, '78
Poliovirus	2 days @ 35 °C	98.5%	Barnett, '78
Cholera vibrio	14 days @ ambient	100%	Feachem, '80

Measurements and Analysis

The control of anaerobic digestion requires frequent measurements and analyses of the raw, intermediate, and end products of digestion. Standard Methods for Examination of Water & Wastewater or Simplified Lab Procedures for Wastewater Examinations should be consulted as to the specific procedures for making the analyses. Whenever possible continuous recording instruments should be used for the measurement or analysis.

A. Raw Sludge

1. Total and volatile solids concentrations
2. Volume of sludge pumped to the digester per day
3. pH
4. Alkalinity

B. Sludge in Digester

1. Temperature
2. pH
3. Total and volatile solids concentrations
4. Volatile acids
5. Alkalinity
6. Quantity transferred to second stage or other points

C. Digested Sludge Withdrawn

1. Quantity
2. Total and volatile solids concentration

D. Gas

1. Rate of gas production
2. Composition of gas (CH_4, CO_2, H_2S)
3. Temperature

II. E. Supernatent

1. Quantity removed
2. pH
3. Volatile acids
4. Total and volatile solids concentration
5. Suspended solids
6. BOD or COD

F. Other (as needed)

1. Temperature throughout the tank to indicate the effectiveness of mixing.
2. Sounding of the tank to detect the presence of scum or grit deposits
3. N_2 and O_2 analysis of digester gas to detect the presence of leaks.

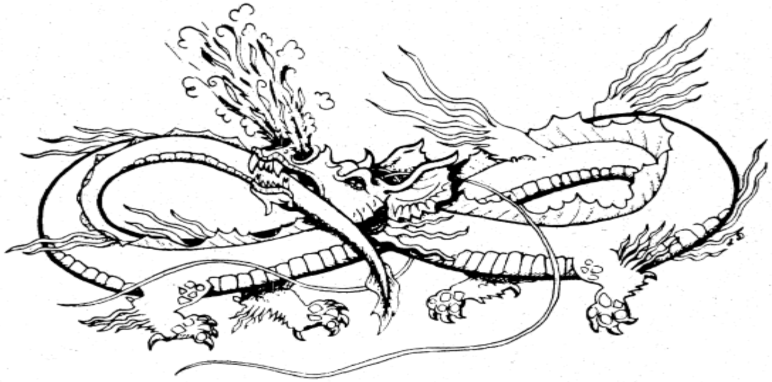
Temperature

pH

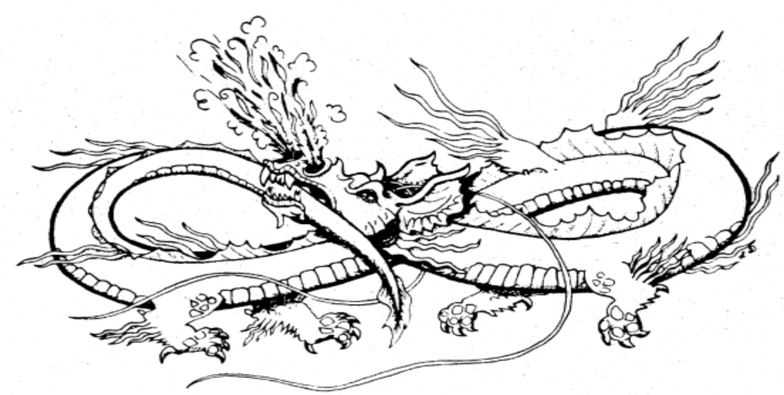
pH

Gas production

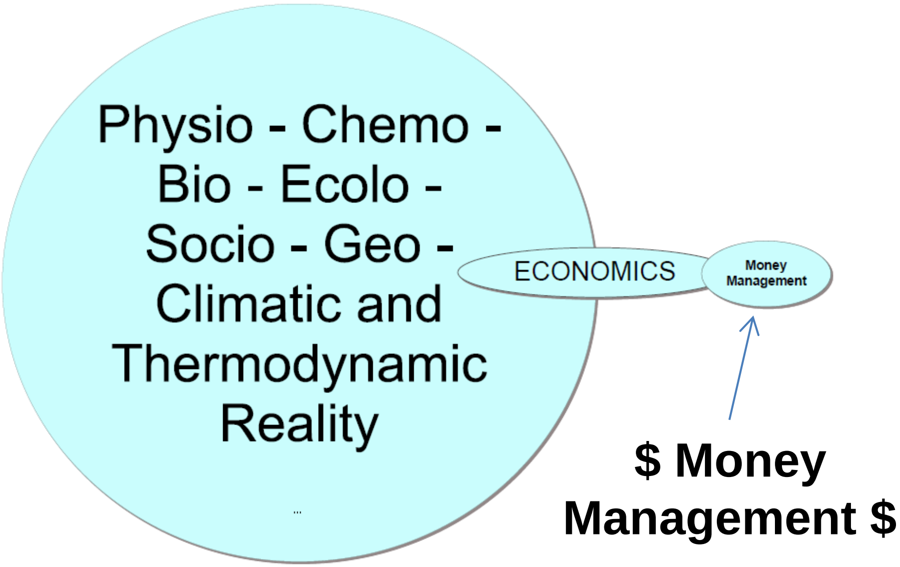
pH



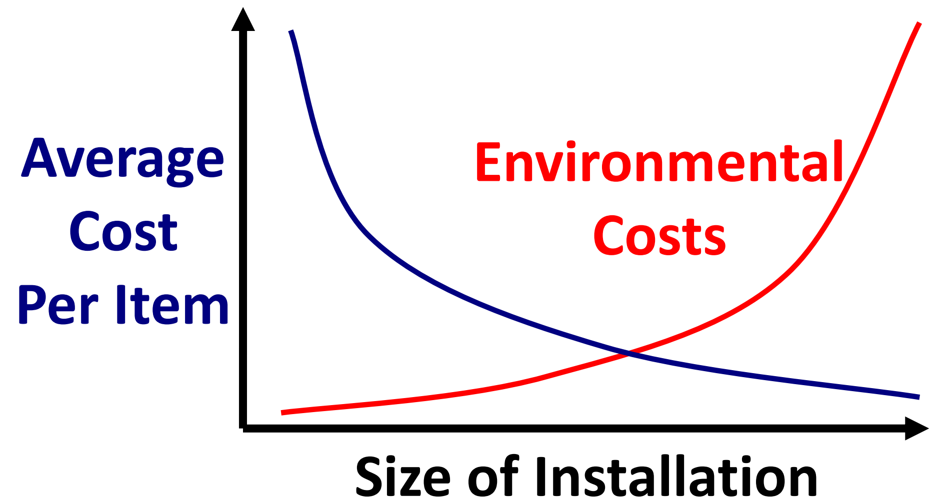
A note on Societal Economics and Monetary Finance



A brief note on the current state of the field of ECONOMICS



Economies of Scale



Industry Type	Generating Potential (kW)	Farm Size	Methane Avoided (MT)	Avoided CO_2 (MT)
Swine	25 100 200	Small - 500 Sow Medium - 1,500 Sow Large - 2,500 Sow	60 250 500	1,500 6,000 12,000
Dairy	25 80 150	Small - 300 Milkers Medium - 750 Milkers Large - 1,500 Milkers	60 200 375	1,500 4,800 8,900

THE ECONOMICS OF NATURAL GAS SOURCES

FOSSIL GAS - MARCELLUS OR WHEREVER	RENEWABLE GAS - ORGANIC RESIDUE-GENERATED

BOTH HAVE CAPITAL, DEVELOPMENT, INFRASTRUCTURE, OPERATING AND MAINTENANCE COSTS

THE DIFFERENCE LIES IN THE EXTERNALITIES

Environmental Degeneration	Environmental Regeneration
Water contamination -- from exploitation, fracking, distribution, use, etc.	Water sanitization, conservation, and productive use, etc.
Air contamination -- from exploitation, fracking, distribution, use, etc,	Air de-contamination -- from odor control, replacement of fossil and less-efficient biomass fuels, carbon sequestration, etc.
Soil ecosystem contamination and destruction	Soil ecosystem regeneration and maintenance - increasing humus and carbon sequestration [and production potential]
A source of nitrogen fertilizers, explosives, etc.	Total conservation of nutrients for local re-growth
Dependent on highly subsidized transportation	Local management, production, and distribution
Centralized Control	Local Self-reliance
Increasing atmosphereic carbon load	Carbon sequestration and recirculation
Any enviromental tax liabilities	Any environmental and carbon tax credits

Economics 603

"The Invisible Hand"

Requires full environmental and social cost/benefit pricing to work for the common good

"Markets"

Exist if and only if market prices represent full costs and benefits

"Economies of Scale"

Almost always fail to consider the often huge environmental costs of scale

The "CC-PP Game"

Commonization of Costs and Privatization of Profits, *Garrett Hardin*

"Bio-Economics"

Recognition that thermodynamic and bio-physical reality trumps dollar manipulation
Nicholas Georgescue-Roeten, 1976
independently, RAHamburg, 1983

"Externalities"

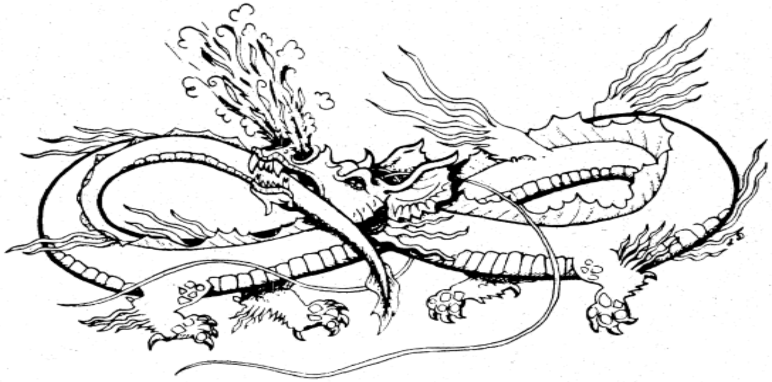
With a cyclical perspective, many opportunities for environmental, social and business profit -- Doing well by doing good

Sustainability va'v Regeneration

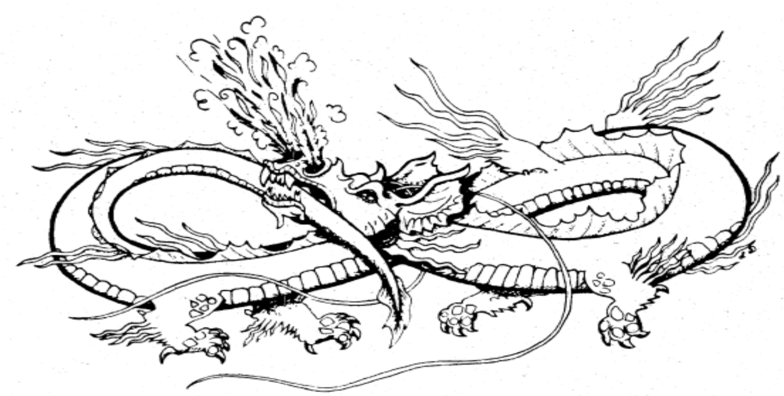
Covered lagoon for gas collection at swine facility, NC, 1995

Often-government-funded support for over-centralized corporate food production – Ignoring social and environmental costs – But seeking those carbon credits – for that pseudo-bottom line.

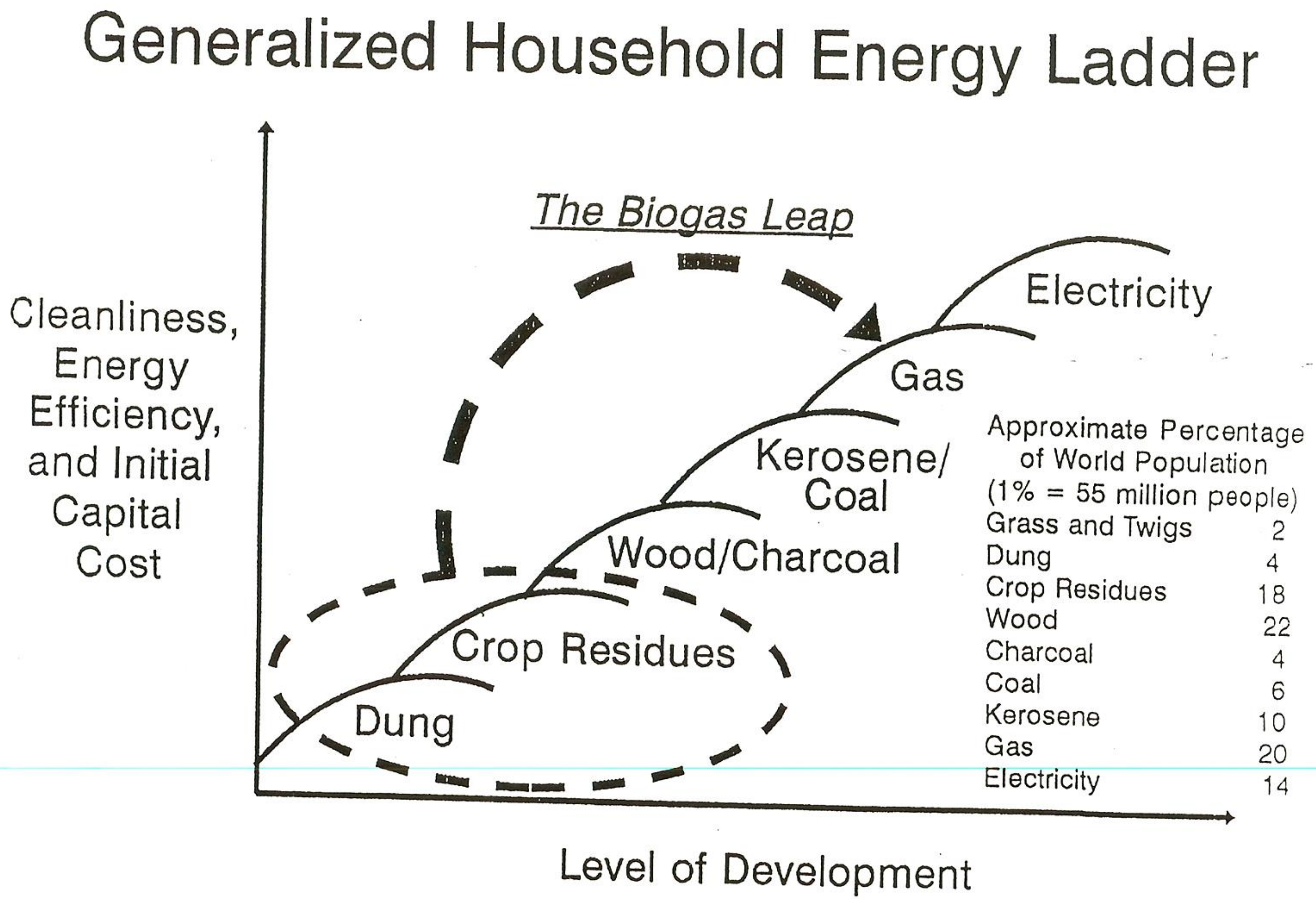
Lipstick on a pig!



A REMINDER
OF
GLOBAL IMPLICATIONS



The Biogas Leap



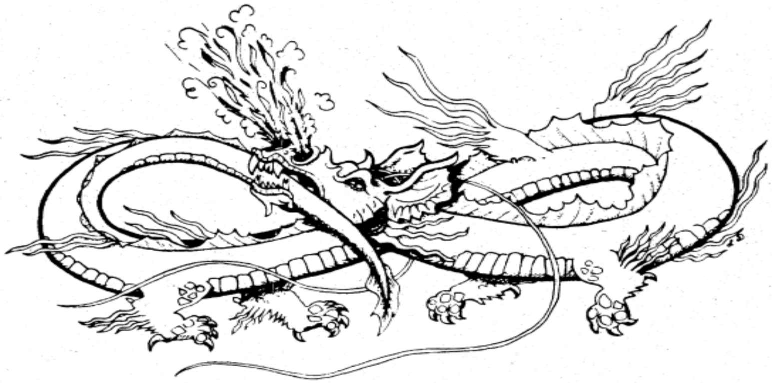
(Source: After Smith, K.R. and Y.C. Liu. 1993. "Indoor Air Pollution in Developing Countries," in EPIDEMIOLOGY OF LUNG CANCER, ed. by J. Samet. New York: Marcel Dekker.)

Some fuels potentially replaced by Digesters

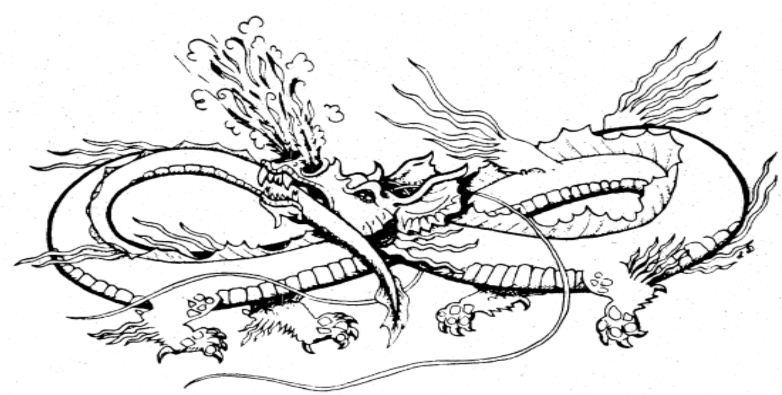
Cow patties drying on Kathmandu wall before use as cooking fuel, Nepal, 1976

Coal briquets from pressed "fines" – primary household fuel, China, 1987

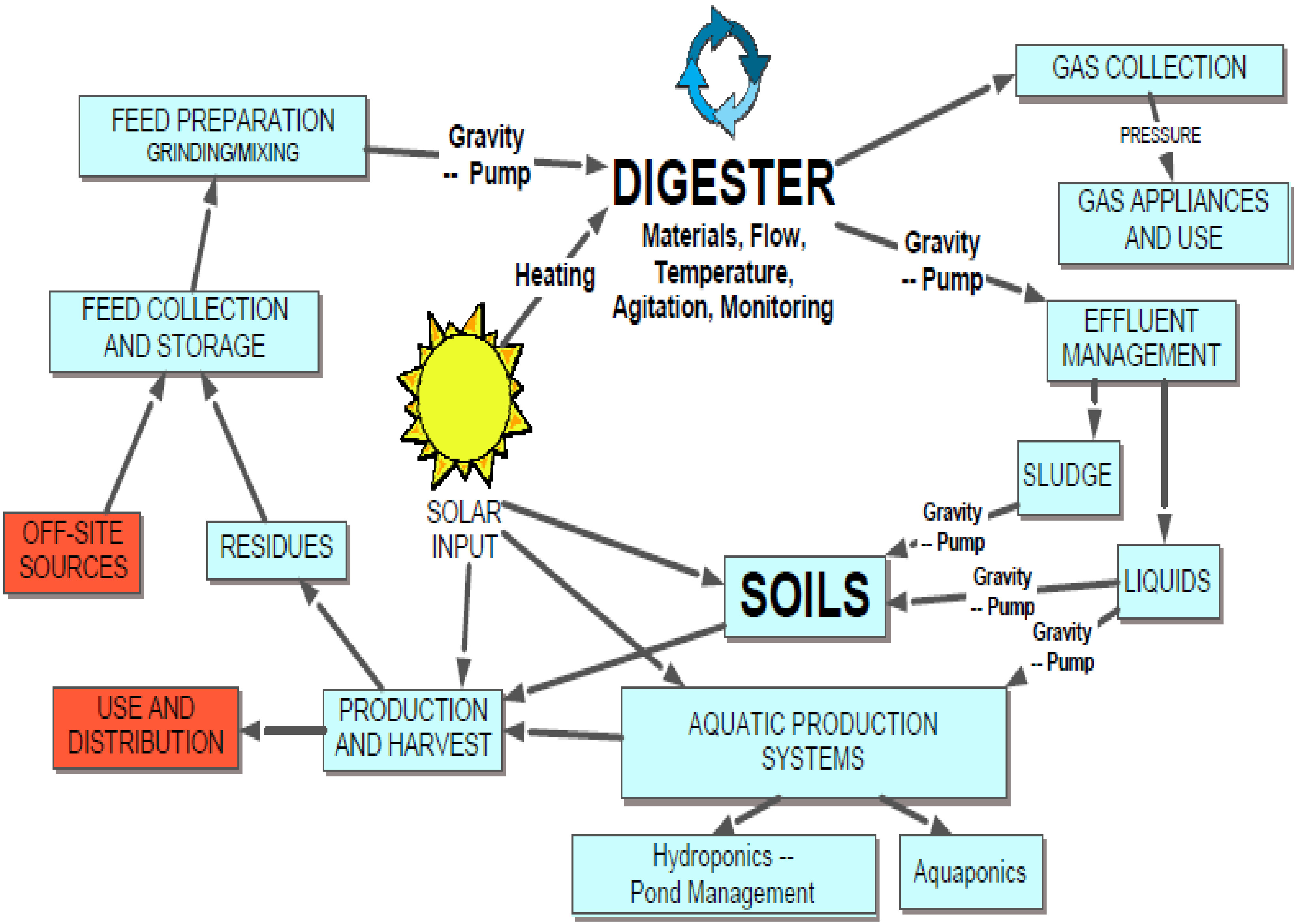
Crop residues, Firewood, Charcoal, Coal, Kerosene, et al.



BROAD DIGESTER DESIGN CONSIDERATIONS

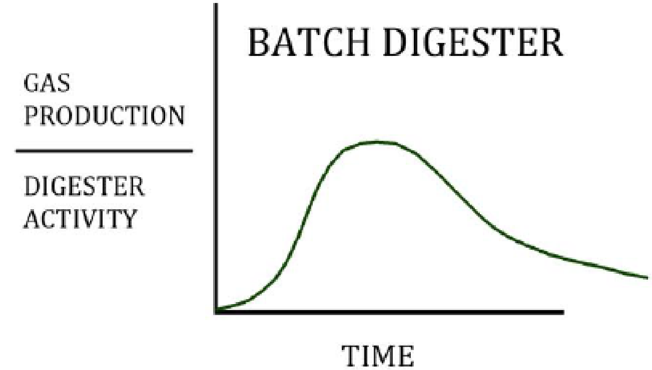


BASIC BIOGAS SYSTEM CONSIDERATIONS

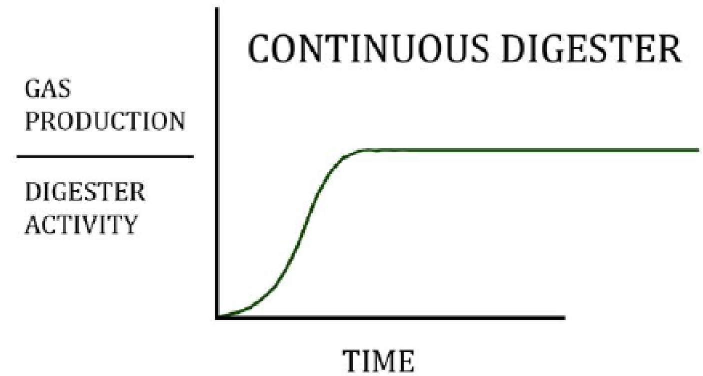


Batch, Continuous, Multiple-Batch and Extended-Batch Feeding Regimens

Batch – All feed loaded at start and emptied at end – Except for seed left for next batch!; Burnable gas after 1-2 weeks, with gas peaking and falling off for months.

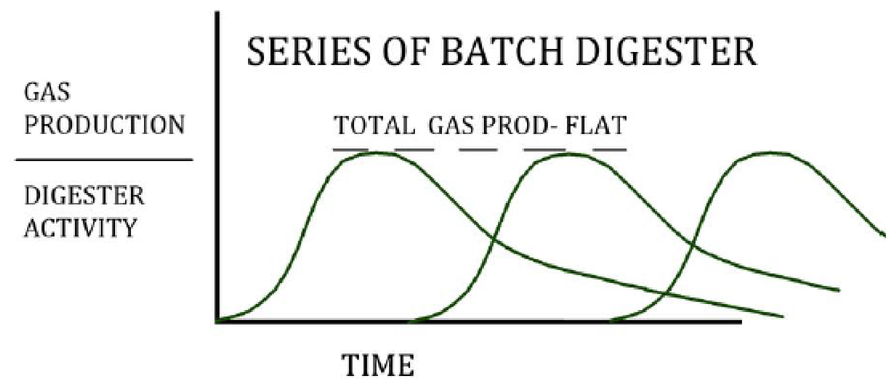


Continuous – Constant feeding to maintain specified gas production and digester activity from a single unit.



Multiple-Batch – Coordinating several digesters in the batch mode – for gas needs and nutrient management.

Extended-Batch – Loading a large portion of feed and starter to begin; wait a few weeks for combustible gas to begin; then feed sparingly over weeks, months; empty when appropriate



Batch-Load vis-a'-vis Continuous Digester Management

Batch	Continuous
Nearly complete loading and emptying all at one time	Regular (daily) feeding and effluent management
Requires more overall digester volume	Requires less overall digester volume
Much leeway with temperature	Constant temperature far the best
More variation is feed possible	Constant feed or slow changes best
With enough digesters, digestion process maybe allowed to proceed to completion – for maximum gas and sanitation	The aim is "adequate" decomposition, gas production and sanitation
With enough digesters, effluent materials may be stored until weather permits convenient distribution and use	
Down time permits simpler maintenance, repairs and upgrades	Requires constant functionality of pumps, piping, etc.
Multiple digesters and extended-batch feeding permit regular gas production	
Much less worry about Scum and Foaming	Need to design for scum management
Agitation less important	Agitation necessary to facilitate process
Leaving some digested materials in the digester provides quicker startup	

A Batch Digester Option?

Draco I – solids to be emptied by hand

Digester Start-Up

The best startup inoculant is fresh solids from a digester that is generating biogas vigorously from the same material you intend to use.

Generally, a couple days' worth of charge with some fresh manure will result in a burnable gas (>50% methane) within two weeks or less.

- **Often powdered lime or other pH buffering material is helpful**

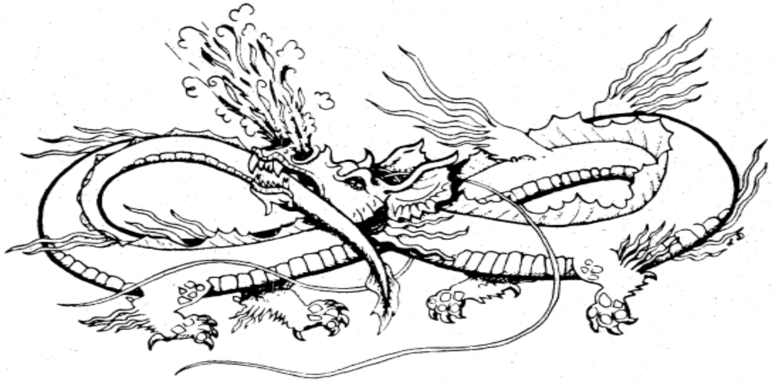
RAH, 2014: For a continuous digester,

-- Start with a water-filled digester –

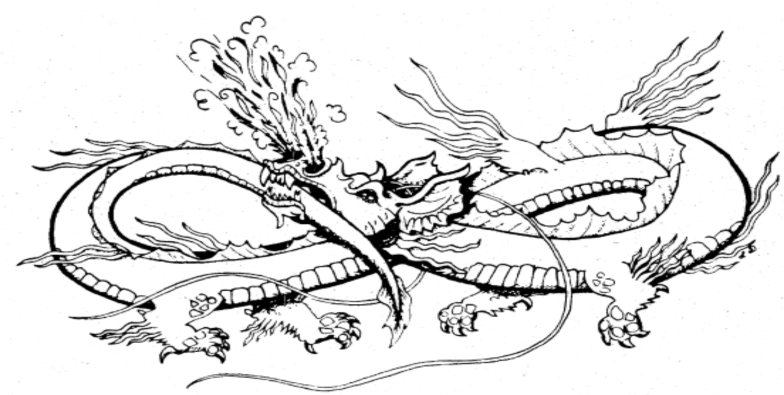
-- Add seed for several days --

-- Gradually introduce hoped-for feeding regimen –

-- Adjust as recognized.



DIGESTER DESIGN



Basic Digester Designs

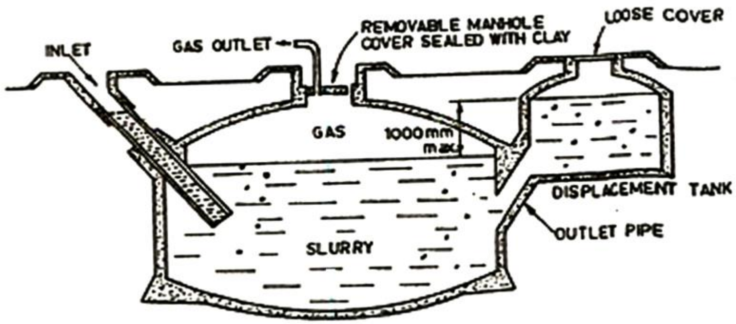


Figure 1 Fixed dome (Chinese) digester

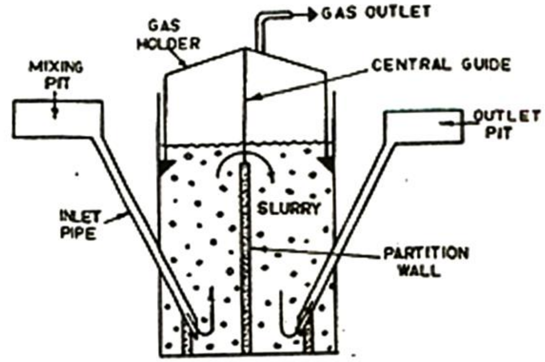


Figure 2 Floating cover (Indian) digester

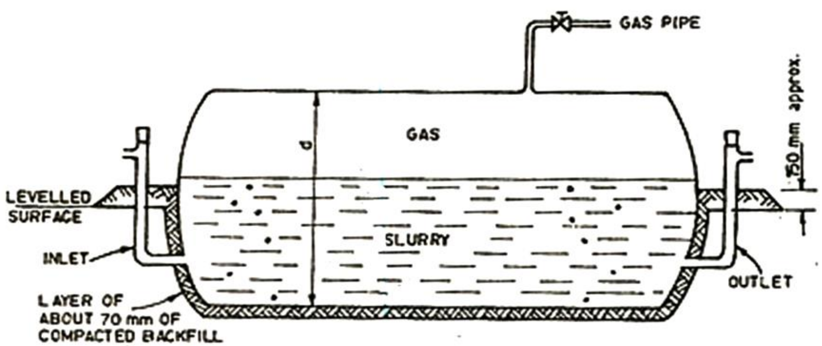


Figure 3 Bag (Taiwan) digester

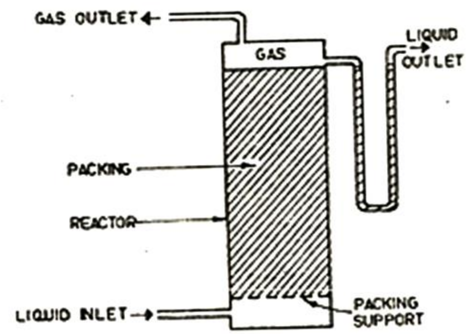


Figure 5 Anaerobic filter

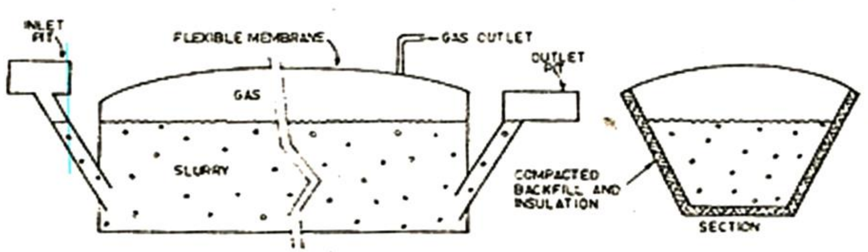


Figure 4 Plug flow digester

BASICALLY,

Rounded and mixed -- as the stomach

OR

Longer and Narrow -- as the intestines

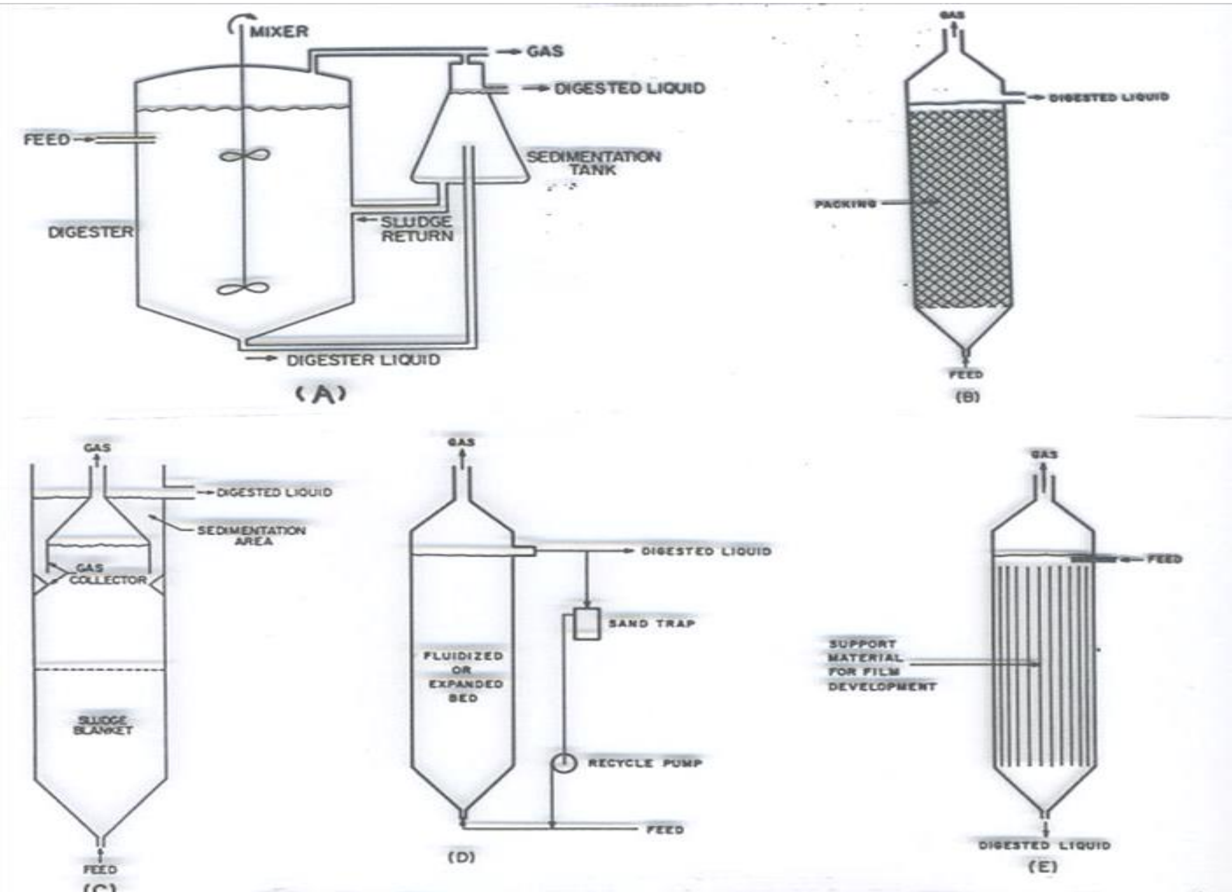


Fig. 1. Sketches of the anaerobic contact (A), anaerobic filter (B), upflow anaerobic sludge bed (C), anaerobic fluidized or expanded bed (D), and downflow stationary fixed film (E) reactors.

Higher technology, filter designs

Generally most appropriate for dilute residue streams – whey and the like

Anaerobic Treatment of Whey[a]

Anaerobic process	Temperature (°C)	Waste loading rate ($kg/m^3/day$)[b]	Removal (%)
Anaerobic filter	22–25	1.9 COD	97–98 (COD)
Conventional	35	2.1 BOD	99 (BOD)
Contact process	35	4.3 BOD	99 (BOD)
Fixed film	28–31	8.9–27 COD	7–93 (COD)
Expanded bed	35	8.2–22 COD	61–92 (COD)

[a]Adapted from (45).
[b]Kilogram of noted parameter per cubic meter of reactor volume per day.

Some Common Problems with Large Commercial Continuous Digesters in the US [and elsewhere]; as well as many smaller systems

3 Major Design Flaws

* Insufficient digester heating and/or heat retention
* Poorly designed feedstock collection, mixing and delivery system
* Wrong size digester vessel, engine-generator sets, and all associated equipment for the operation

Mechanical Failures of System Components

* Electrical engine-generator sets (~40 % of cost of "smaller" systems)
  - hydrogen sulfide in the gas
  - high moisture content of the gas
  - fluctuating gas quality and quantity
  - parts availability
  - unavailability of smaller engines, i.e. 25-65 kW
* Feedstock (usually chopper) and effluent pumps
  - rocks and miscellaneous metal/plastic inclusions
  - seal and whole pump replacements
* Gas cleaning, delivery and storage systems
* Electronic control panels and wiring
  - exposure to hydrogen sulfide, high moisture and heat
* Pressure relief valves

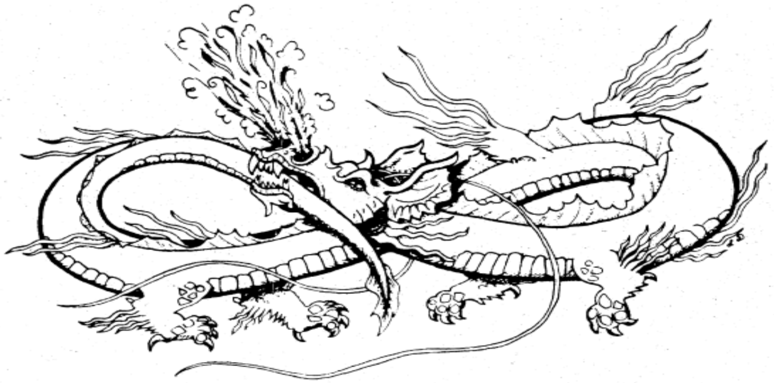
Operational and Biological Problems

* Scum build-up and feedstock separation (primarily with dairy)
* System Start-up
* Foaming
* Changes in feedstock composition, temperature and pH
* Build-up of inert, inorganic solids in digester vessel
* Toxicity or pH shocks
* Microbial imbalance

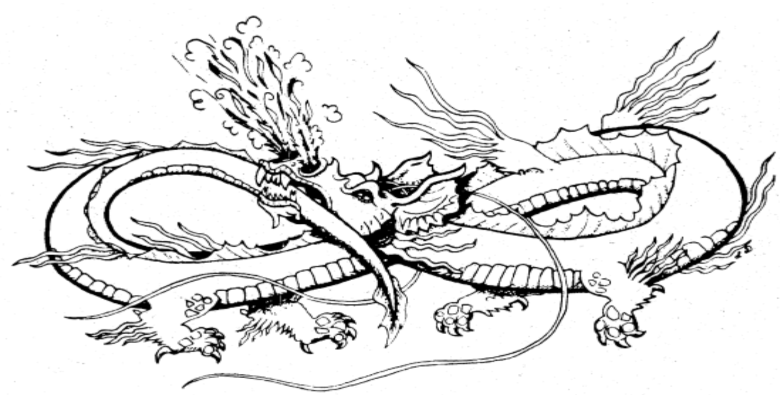
Integration of Digester with Overall Operation

* Need to fit into existing operational schedules and local utility constraints
* Requirements for equipment repair
* Seasonal fluctuations -- gas and effluent utilization

Reconsider Batch- and Extended–Batch Alternatives



DIGESTER DESIGN – FULL-MIX SYSTEMS



Full-Mix Digesters

Research digesters, Cornell, ~1977

Dairy digester, Ithaca, NY, ~1983

Engine and dried solids storage shed for under-ground dairy system, Lancaster, PA, 1987

250 gal mixed digester in solar room Minnesota, ~1978

XXX

Full-Mix Digesters

China – Nanyang distillery executives and others on top of one new 5000 cu m digester w/ other in background – The plan is to provide for all process needs.

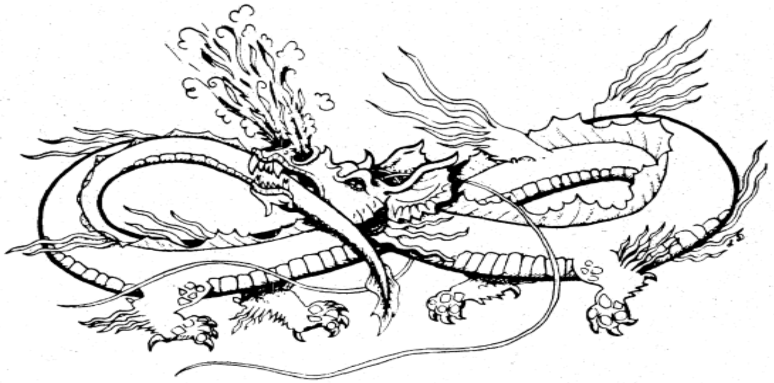
China – Nanyang Distillery – new (1987) 3000 cu m gas storage system for maintaining supply to 30,000 nearby households (replacing coal!)

Full-Mix Earthen Lagoon, Kilby Farm, Colora, MD   Current

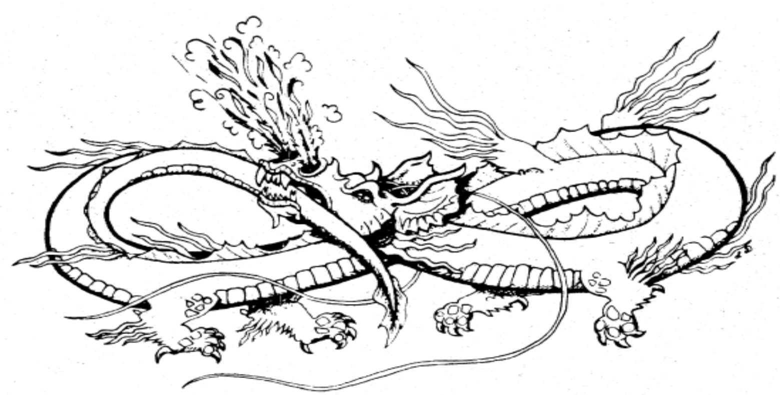
Covered lagoon and operations shed

Scrubber, heater, mixing pump

Engine-generator (inoperative due to inadequate scrubbing)



DIGESTER DESIGN – LARGE-SCALE FILTERS



Up-flow or Down-flow Filters

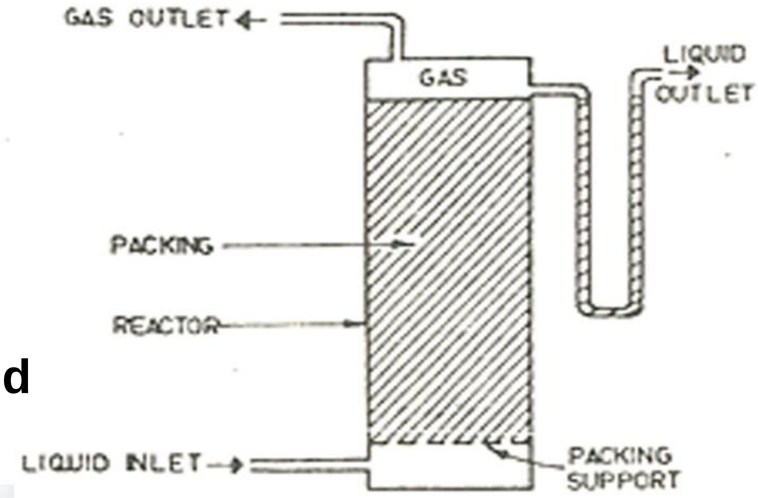
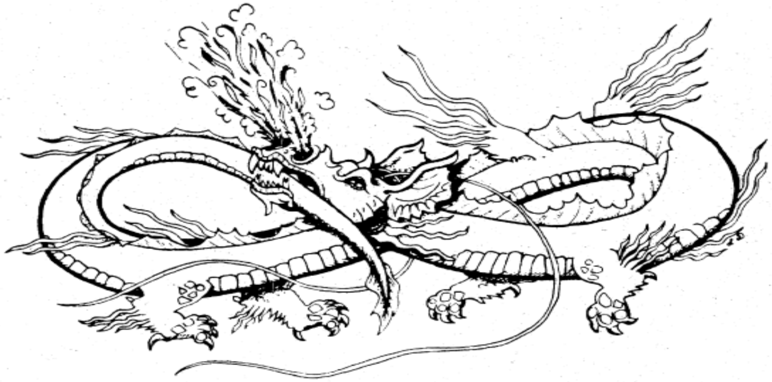


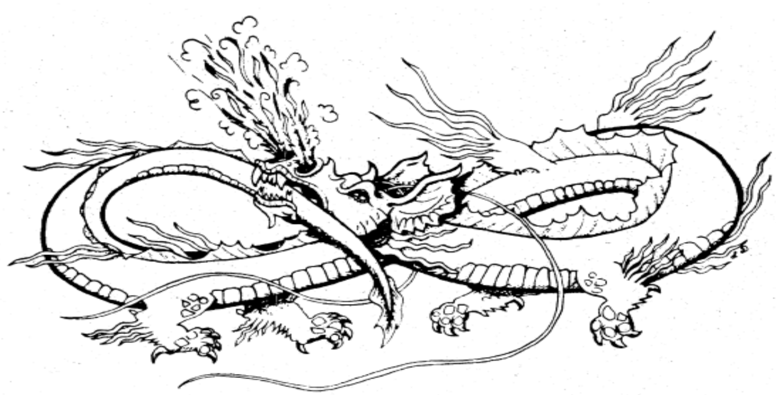
Figure 5 Anaerobic filter

Engine, scrubber and gas storage houses and digesters, Maine's Dairy, Newville, PA 2012

Separated solids composting, Maine's Dairy



DIGESTER DESIGN – MASONRY TANKS, CHINESE DESIGN



Masonry Tanks -- The Chinese System

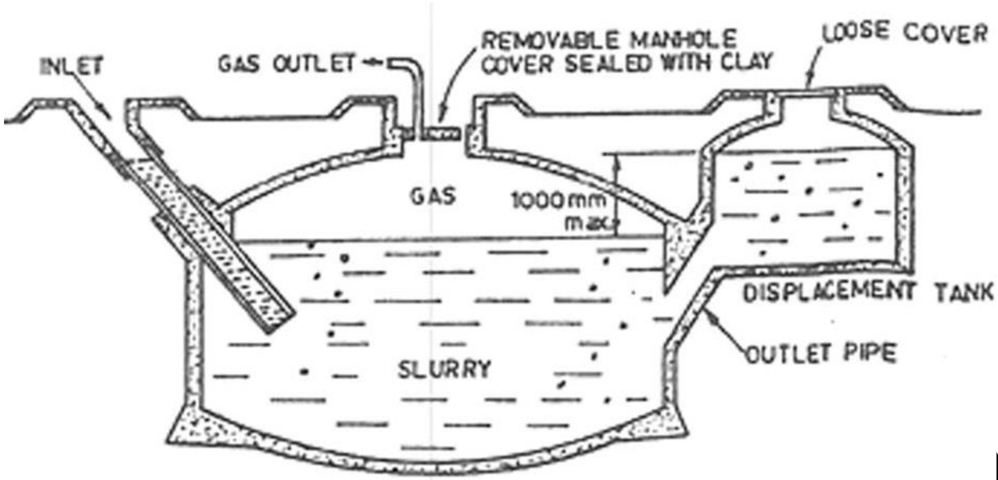


Figure 1 Fixed dome (Chinese) digester

Concrete construction in the Philippines, 1985

Brick construction in China, ~1960s-80s

China – Hunan State Solar Research Center, 1987
Concrete construction with steel forms

Hole smoothing system

Setting inside slip-form for walls

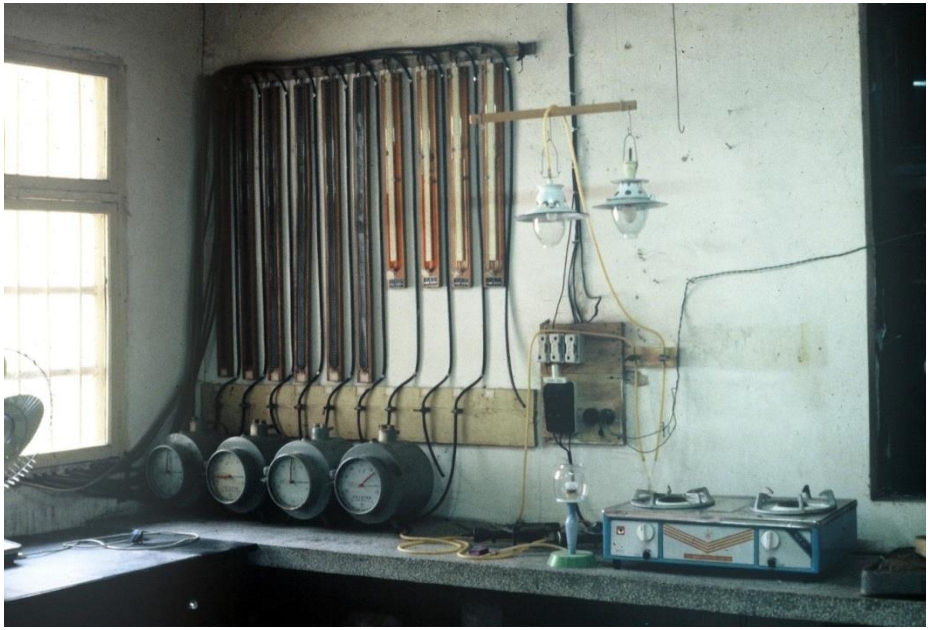
Steel frame set for pouring dome

Dome construction

China – Hunan State Solar Research Center, 1987

Gas storage drums, digester access ports and covers

Monitoring station



Gas holder pressure test unit

One digester dome cleaning port

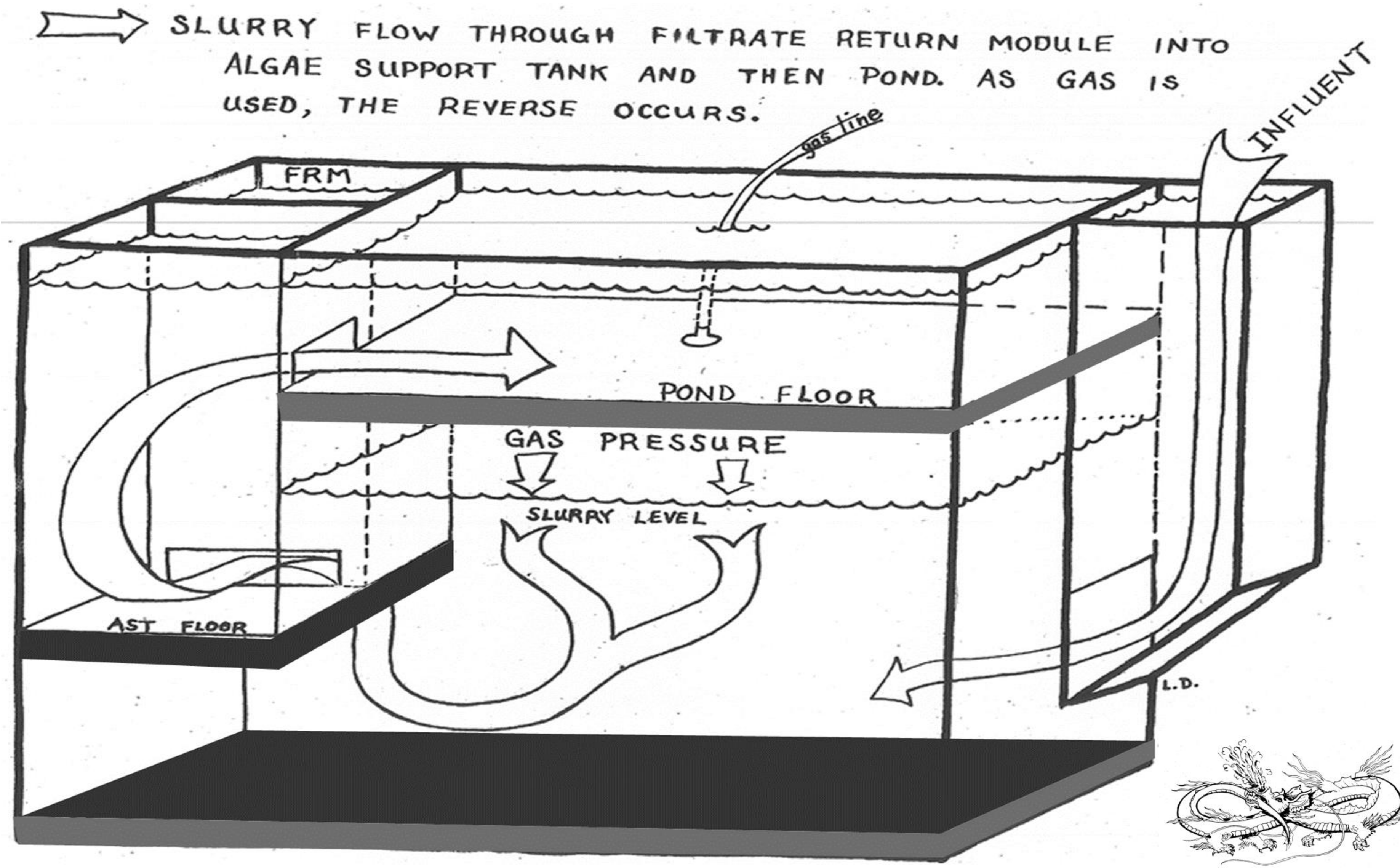
Domed digester construction in Uganda

On-site construction of interlocking, earthen-cement, curved block

SEE: http://www.youtube.com/watch?v=s4EWOoPY5OY

Earlier Chinese Design
Adapted for OARS' Draco I and II

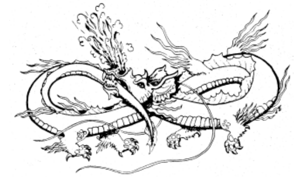
(Found in Bulletin of the Atomic Scientist, 1976)



Fixed-dome (Chinese design) digester with pond growth, Guatemala, 1986

Chinese design masonry digester with pond growth above, Bangalore, India, 1994

The site – on center hillside



OARS'

DRACO I

WV, USA 1980

Integrated Chinese digester, greenhouse and pond

Block and concrete work completed

Completion Open House

OARS' Draco II – WV, USA, 1981

Two larger digesters, much larger greenhouse, increased insulation for year-round use and greatly expanded pond area

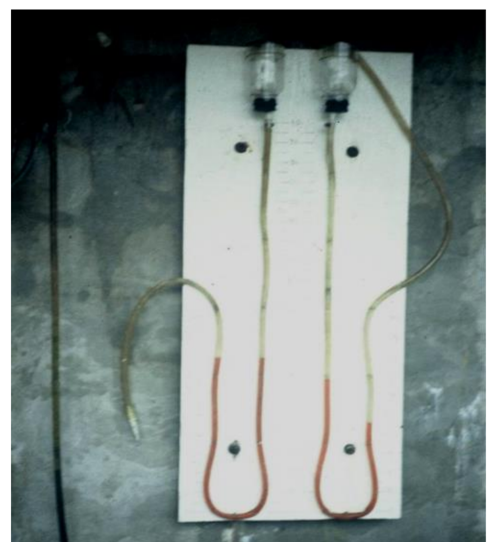
First Fall

Second Fall

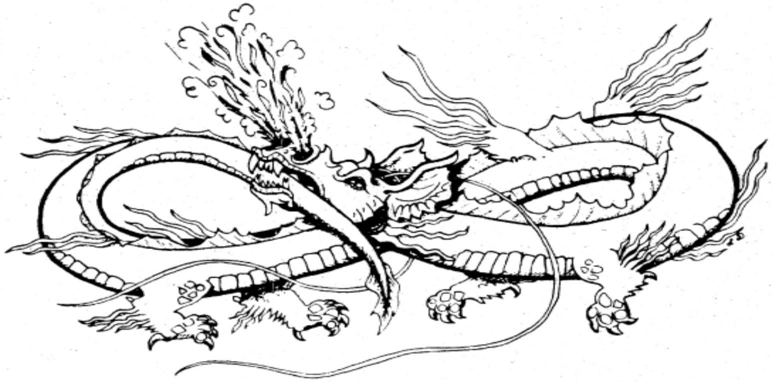
OARS' Draco II

Pond channel extensions in place, solar fans on thermo siphons, WV, 1982

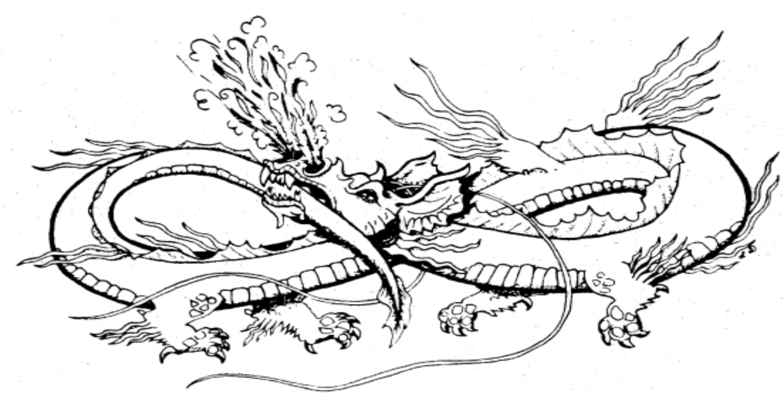
Inside one tank after polyurethane sealing, from inlet end; note also cleaning port, surface break-up pipes



Manometers: note ~7" difference on right side -- indicating biogas pressure



DIGESTER DESIGN – FLOATING DRUMS*, INDIAN DESIGN



* After early British sanitation efforts

Floating Drum - Indian System

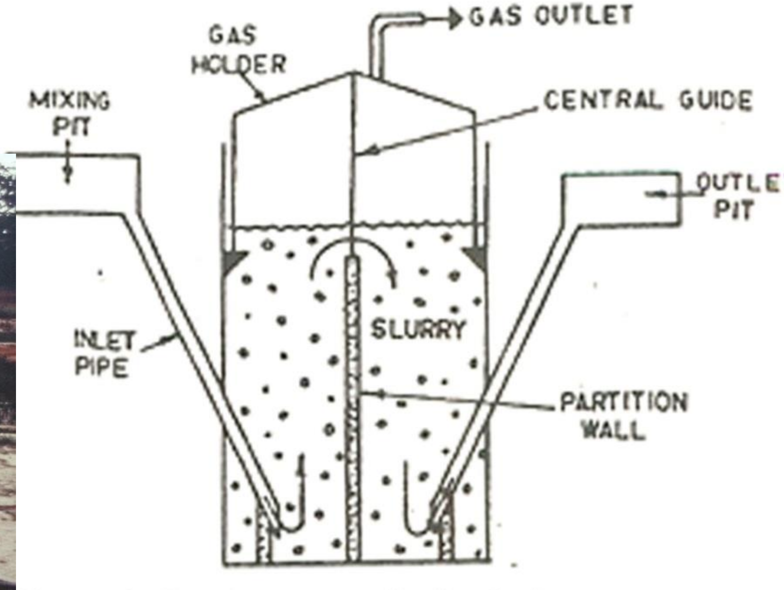


Figure 2 Floating cover (Indian) digester

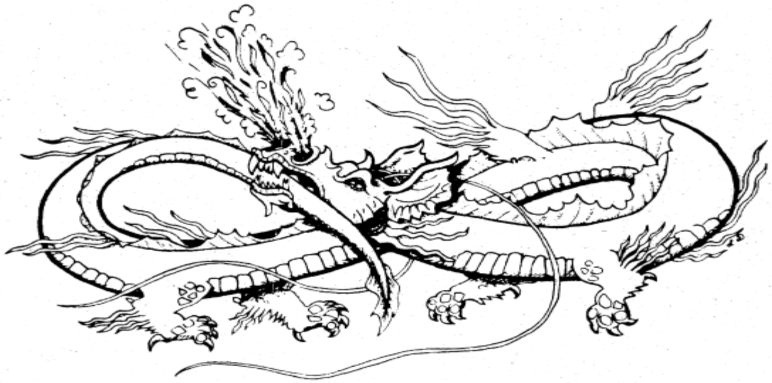
Biogas (Gobar Gas) research station; solar heating, India, 1978

Village digesters; drying beds for sludge, near Bangalore, India, 1994

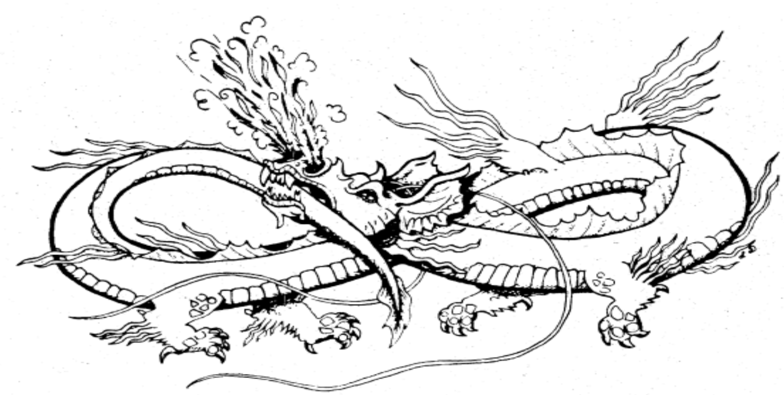
STAND-ALONE FLOATING DRUMS -- Guatemala, 2009

Floating drum and slurry tank for Indian design
Penn State, 1977

History – Indian design chicken digester, Wisconsin, 1977



DIGESTER DESIGN – PLUG-FLOW SYSTEMS



Plug-Flow Digesters

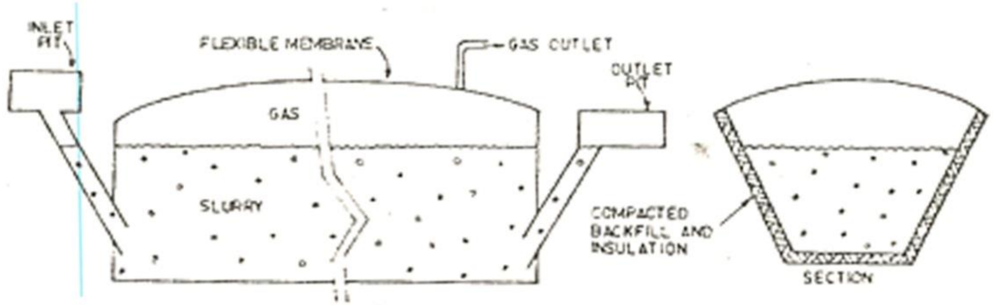


Figure 4 Plug flow digester

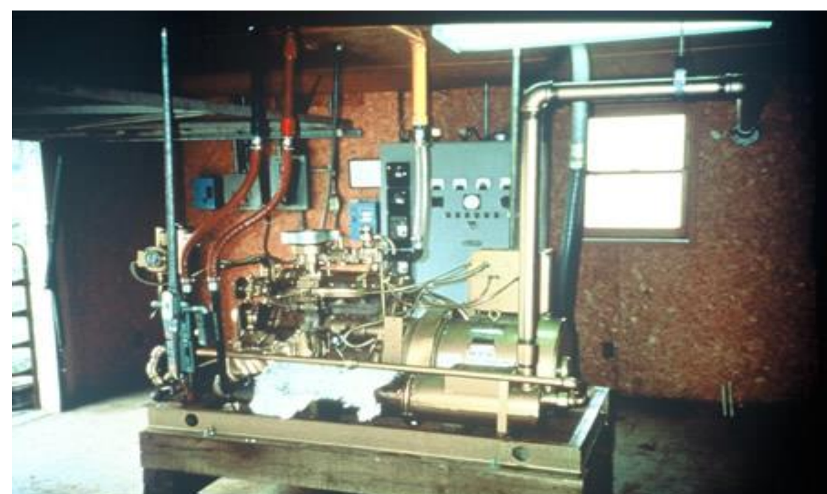
Dairy digester insulated for winter, Cornell, 1980

History – Plug-flow, dairy cow residue digestion research, Cornell U., ~1978,

Buried plug-flow dairy digester with gas storage, Minnesota, 1978

Culvert in place

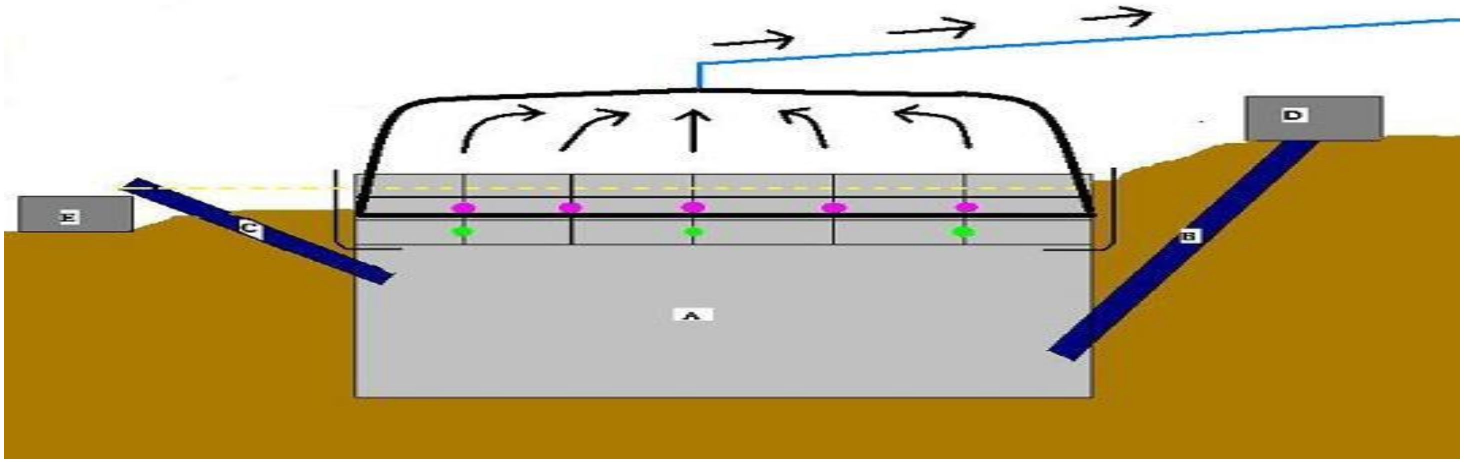
Engine-Generator in shed

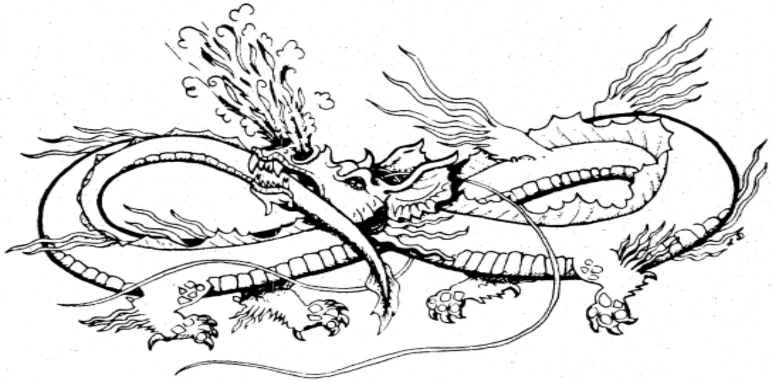


Plug-flow dairy digester, Gettysburg, PA, ~1990

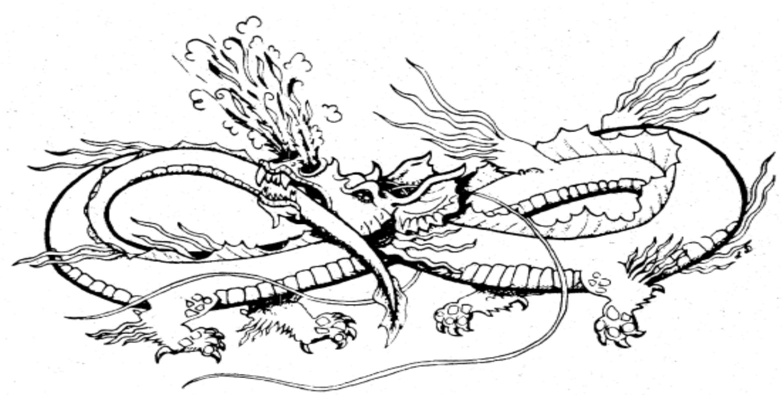
China – 2, 2000 cu m digesters at Nanyang Distillery (1987)

COSTA RICA: PLUG-FLOW VARIANT, 1990s





DIGESTER DESIGN – SAUSAGE SYSTEMS



“Sausage” Digesters

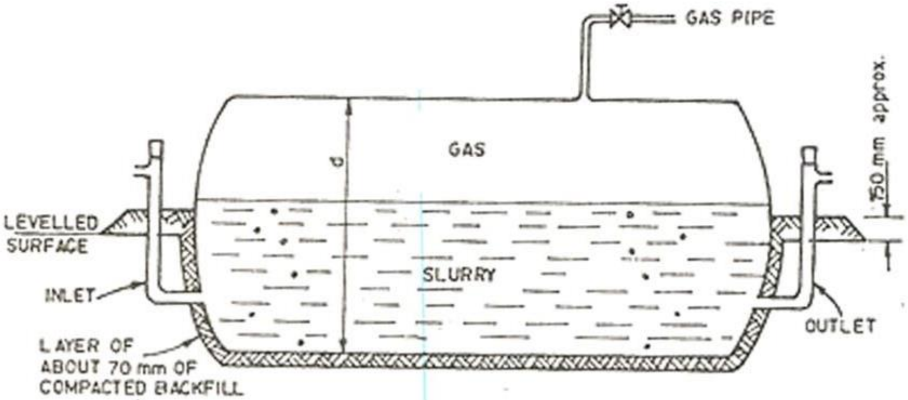


Figure 3 Bag (Taiwan) digester

Red mud plastic digesters, Taiwan , 1983

Red Mud Plastic Digesters – Taiwan, 1983

Sausage Digesters

Most simply an in-ground tube with no sun protection and effluent flow into a collection pit.

Polyethylene tubes are very cheap but quite…fragile

Bolivia, mid ‘00s

4 cu m, Carbondale, CO

12 cu m, Puebla, Mexico

Two 40 cu m digesters
Merida Mexico

SISTEMA BIOBOLSA
CONTACTO BIOBOLSA

Fiberglass digester construction at Rutan Biogas Workshop, ~1978

Culvert-enclosed, highly insulated polyethylene digesters -- University of Maryland-USDA Beltsville Research Station, 2012

EPDM digester-greenhouse system

Dickinson College Farm, Boiling Springs, PA

Early inner tube digester

Digester pressure test

Gas storage bag

Pieces In place

EPDM digester tube with plastic end caps (in process)

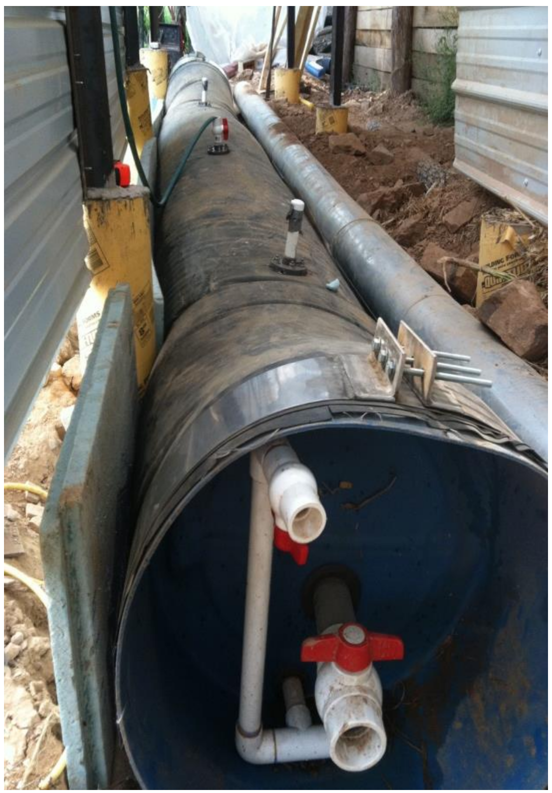
Built at Dickinson College Farm

The Plan -- Placement In a well-insulated trench under a growing table in a greenhouse; photovoltaic forced-hot-air to heat

Being installed in a multi-functional greenhouse at a Perry Co. farm

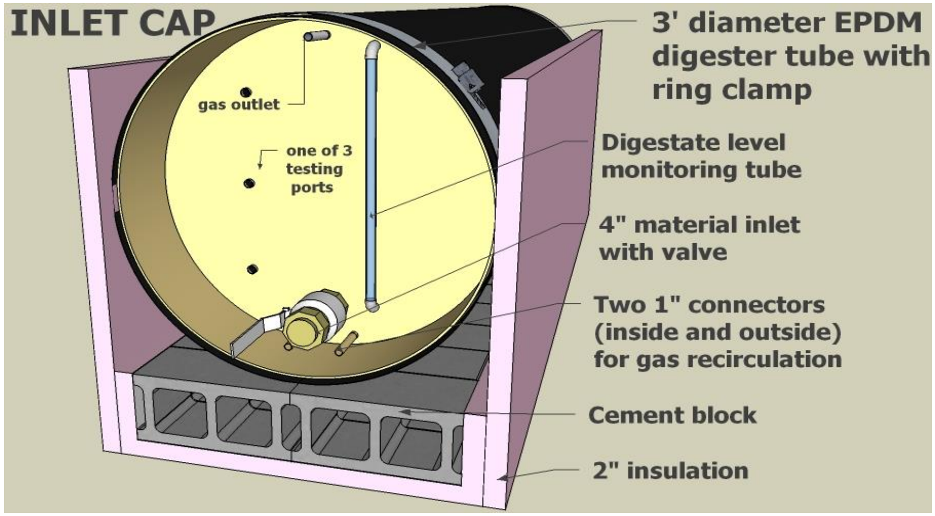
EPDM digester tube with plastic end caps (in process, cont.)

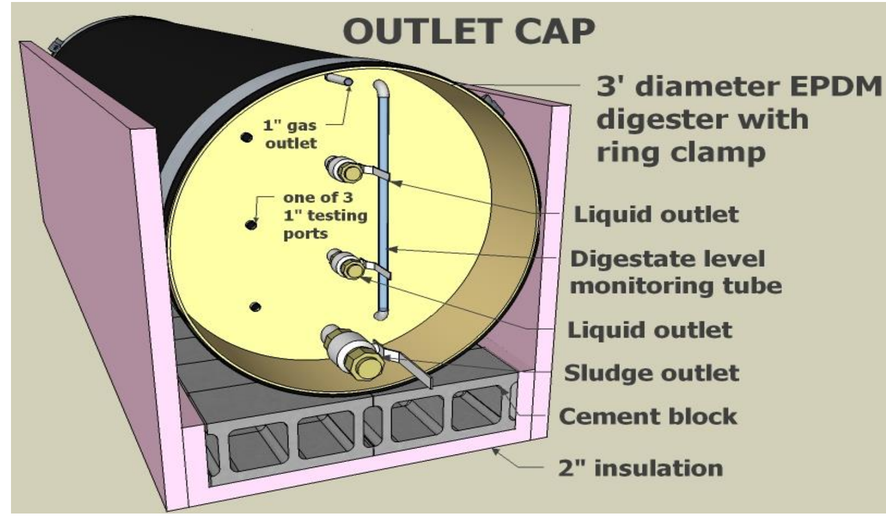
Successful non-leaking water test



Protected digester with Rocket Stove Exhaust

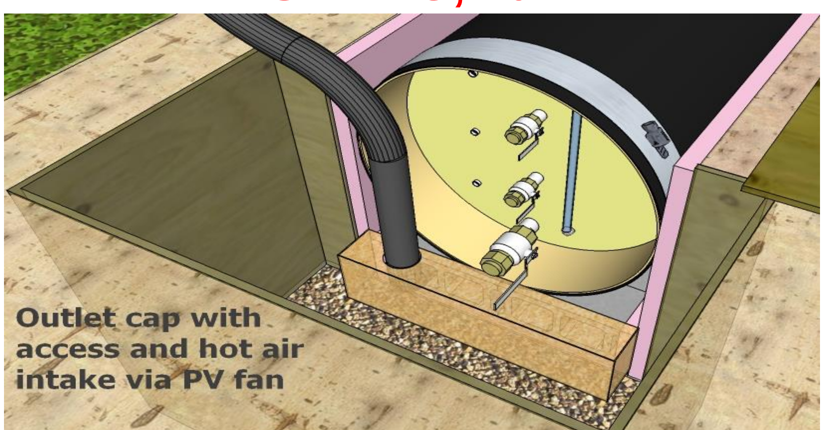
EPDM digester tube with plastic end caps -- NEXT STEP

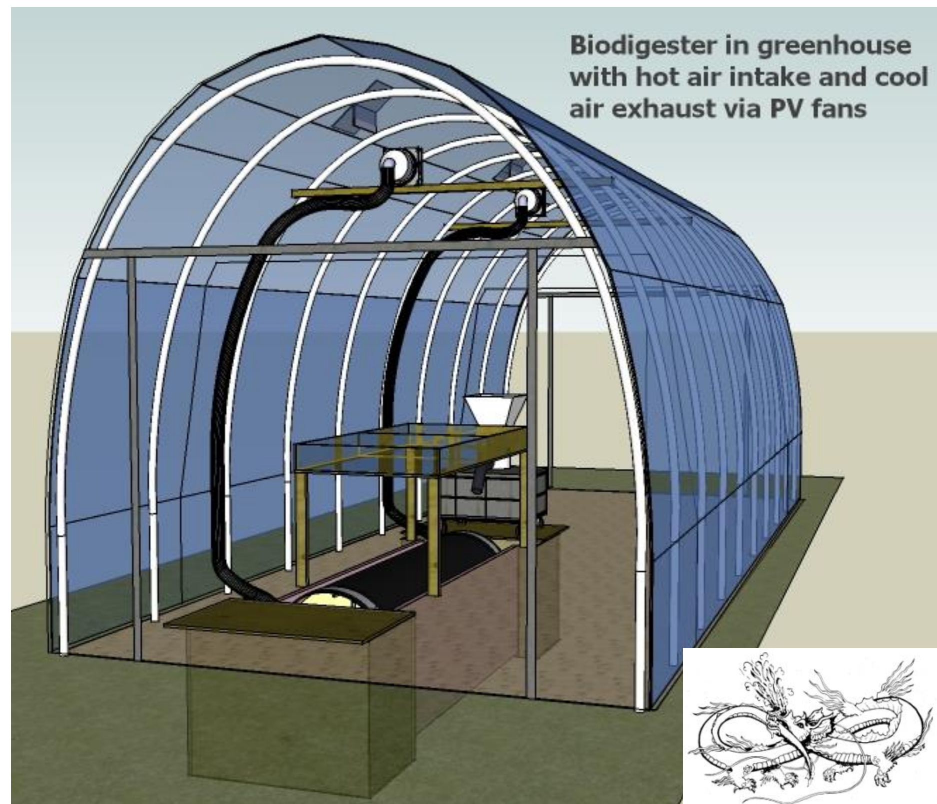




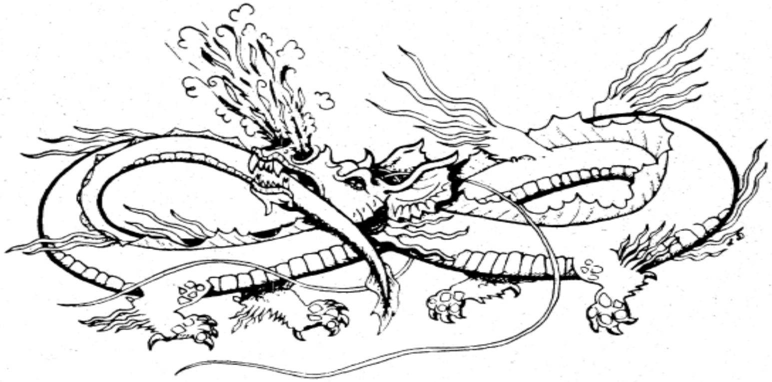
Improvements – FULL use of EPDM roll dimensions
-- NO holes in EPDM tube
-- All ports and gimmicks molded into plastic (prototype in metal/stainless)

DIGESTER PIECES EXPECTED IN SPRING, 2014

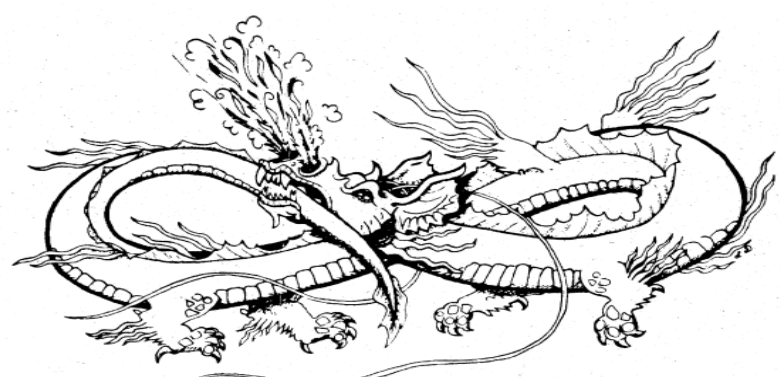




NEEDS A HOME! ???



GAS CONSIDERATIONS



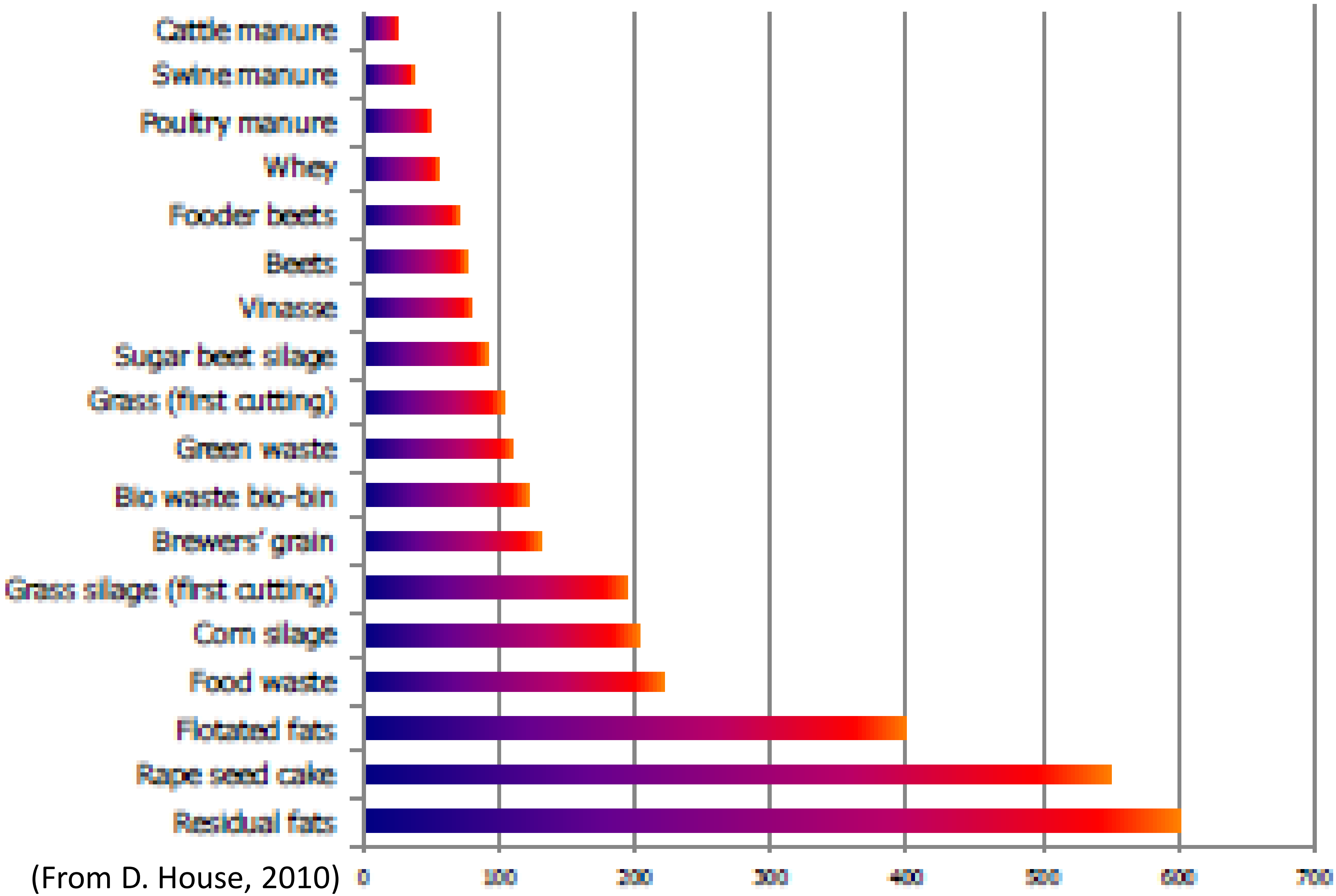
Gas production: vol. biogas / vol. digester

Digesters, at near-optimum mesophilic temperatures, with moderate solids levels (~8-12%), may be expected to produce about 1 vol biogas/ 1 vol digester / day.

Underground masonry digesters in a warm climate may produce 20% to 50% of the digester volume per day

OARS' Draco I produced 50% vol/vol during active seasons.

Biogas Yield – Various Substrates



(From D. House, 2010)

Simple and Purified Substrates

- Lignin
  - Stubborn compound that actually inhibits digestion of other substances when present; plants prefer not to decompose and lignin is part of their defense
- Cellulose
  - Digests well where enough N is present; major source of carbon; paper bags are usually 99% cellulose
- Sugars, starches, alcohols (glycerol)
  - Digest very rapidly, so can cause pH shift if not carefully fed at the correct rate
- Fats and oils
  - Produce the greatest quantity and highest quality of biogas where they can be emulsified

(From D. House, 2010)

Biogas Utilization Options

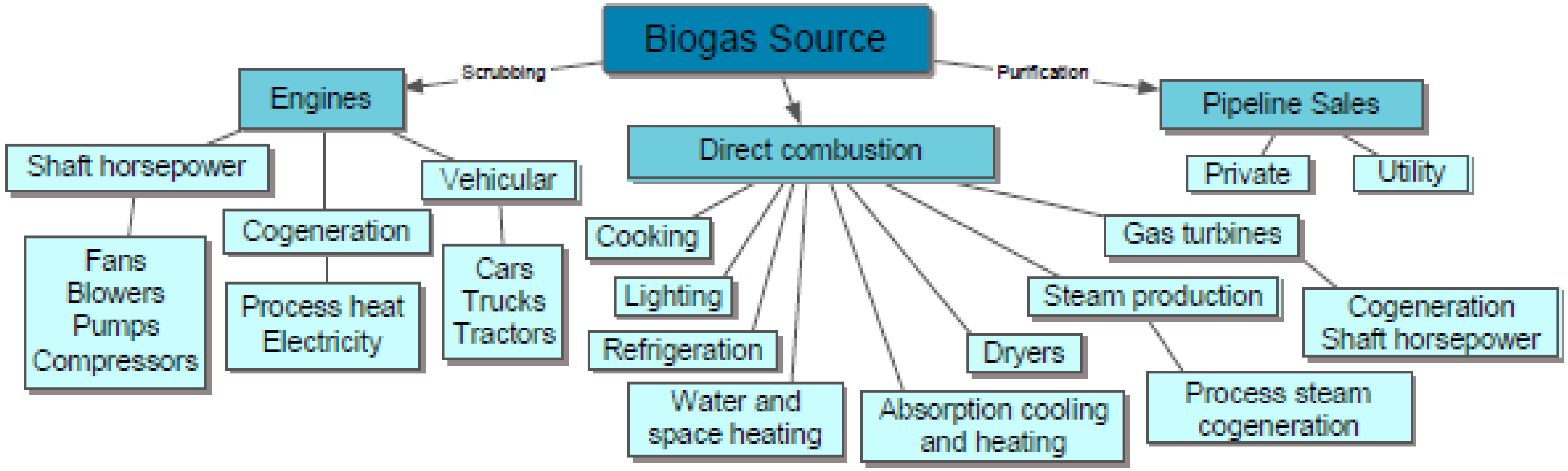


TABLE II-9 Quantities of Biogas Required for a Specific Application(a)

Use	Specification	Quantity of Gas Required: ft^3/hr	Quantity of Gas Required: m^3/hr	Reference No.
Cooking	2" burner	11.5	0.33	5
	4" burner	16.5	0.47	5
	6" burner	22.5	0.64	5
	2"–4" burner	8-16	0.23-0.45	6
	per person/day	12-15+	0.34-0.42+	6
	per person/day	12+	0.34+	7
Gas lighting	per lamp of 100 candle power	4.5	0.13	7
	per mantle	2.5	0.07	6
	per mantle	2.5-3.0	0.07-0.08	5
	2 mantle lamp	5	0.14	5
	3 mantle lamp	6	0.17	5
Gasoline or diesel engine(b)	converted to biogas, per hp	16-18	0.45-0.51	6
Refrigerator	per ft^3 capacity	1	0.028	5
	per ft^3 capacity	1.2	0.034	6
Incubator	per ft^3 capacity	0.45-0.6	0.013-0.017	5
	per ft^3 capacity	0.5-0.7	0.014-0.020	6
Gasoline	1 liter	47-66(c)	1.33-1.87(c)	6
Diesel fuel	1 liter	53-73(c)	1.50-2.07(c)	6
Boiling water	1 liter	3.9(d)	0.11(d)	5

(a) Adapted from Singh (1972).[4]
(b) Based on 25 percent efficiency.
(c) Absolute volume of biogas needed to provide energy equivalent of 1 liter of fuel.
(d) Absolute volume of biogas needed to boil off 1 liter of water.

Residential Air Pollutant Emissions From Energy-Equivalent Fuels (kg)

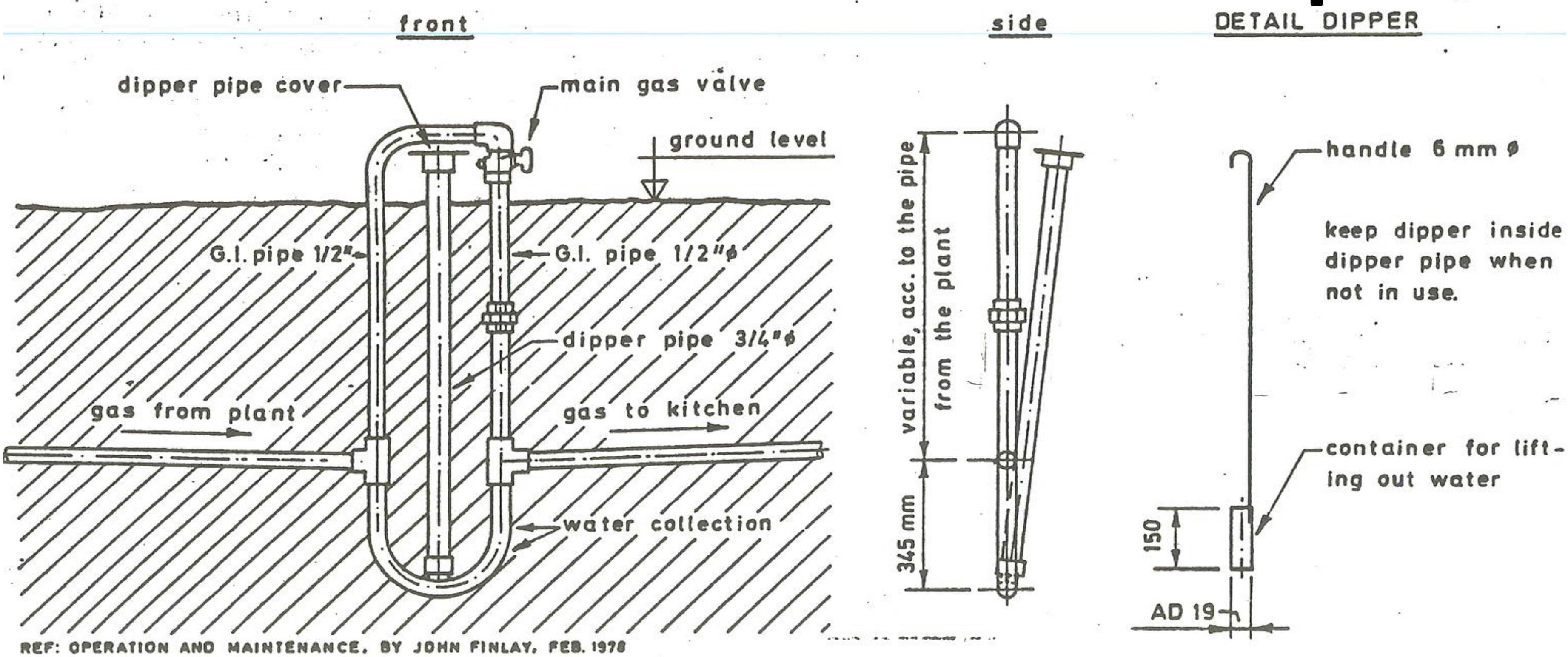
Fuel	*Wood*	*Coal*	*Distillate oil*	*Natural gas*[a]
Efficiency under US conditions (%)	(40)	(50)	(85)	(85)
Fuel equivalent to 1 million MJ delivered	144 metric tonnes	69 metric tonnes	32 900 liters	30 000 m^3
Suspended particulate matter	2 170	520	11	7
Sulfur oxides	86	1 200	1 170	Neg.[b]
Nitrogen oxides	110	270	71	38
Hydrocarbons	1 450	430	4	4
Carbon monoxide	18 790	2 380	20	10

Data adapted from De Koning *et al.*[3]

[a] References 4 and 5.

[b] Neg., Negligible.

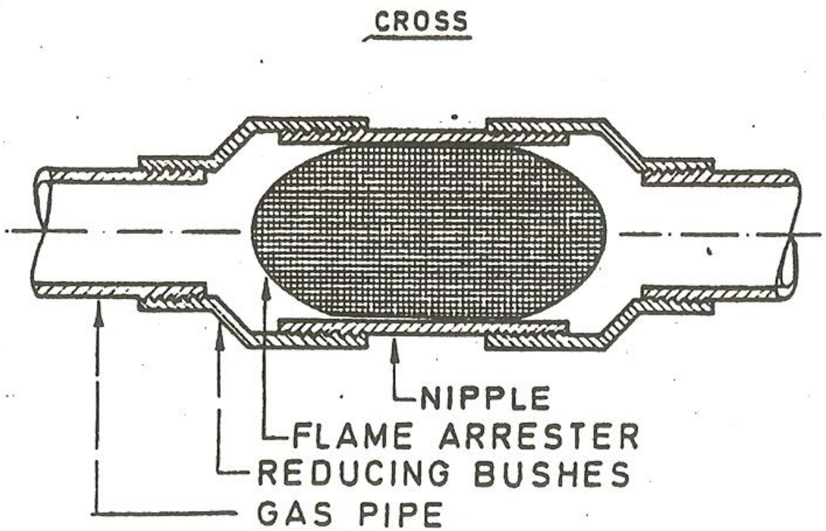
Gas Line Condensation Trap

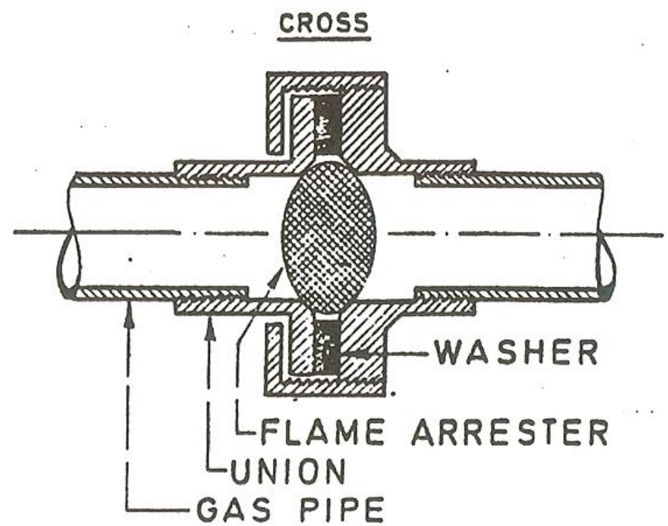


At all low points in the gas lines.

Gas Line Flame Arrester

A flame arrester is a safety device that should be incorporated into every gas line. It is commonly placed either just after the main gas valve near the digester, or just before a gas stove or lamp. It is safer to have one in both places. Its purpose is, in case of an accidental back-fire, to prevent the flame from running down the gas pipe into the collecting drum and causing an explosion.





The arrester can be a ball or roll of fine mesh copper wire (copper, not galvanized wire which would rust away) inserted into the gas pipe. It is sometimes not realised that this necessarily forms an obstruction to the free and full flow of gas. It is therefore recommended that the flame arrester be placed in a length of pipe of slightly larger diameter than the gas pipe, especially if it is placed near the main valve. For a ½" main gas pipe use a 3/4" arrester, for a 1" pipe a 1¼" arrester.

Chinese systems – ferro-cement gas holders

These provide for a more constant gas pressure than gas storage within the dome.

Gas storage and use at the Dickinson College Farm

A polyethylene bag inside
a box on wheels.
A Biogas Rickshaw –
An alternative to piping

Biogas Use – Cooking Burners

Philippines, 1985

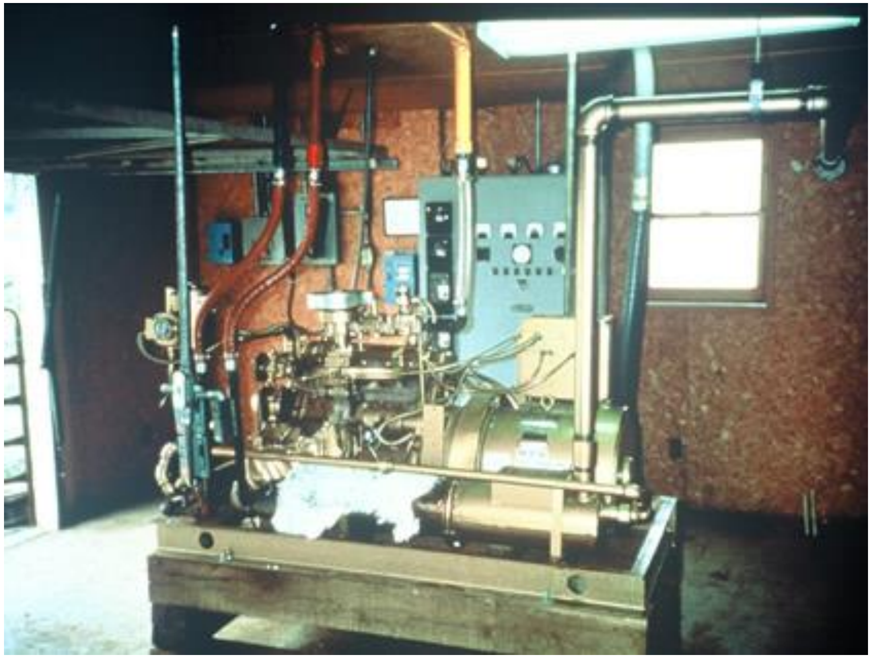
China – biogas and other piping to distillery personnel apartments

Kitchen metering and equipment

Biogas Use -- Lighting

China – 40 watt electric bulb compared to biogas lamp

Biogas Use – Engine-Generator Sets



1 kW -- Chinese

•The biogas must be very well scrubbed of hydrogen sulfide, least sulfuric acid rot the engine.

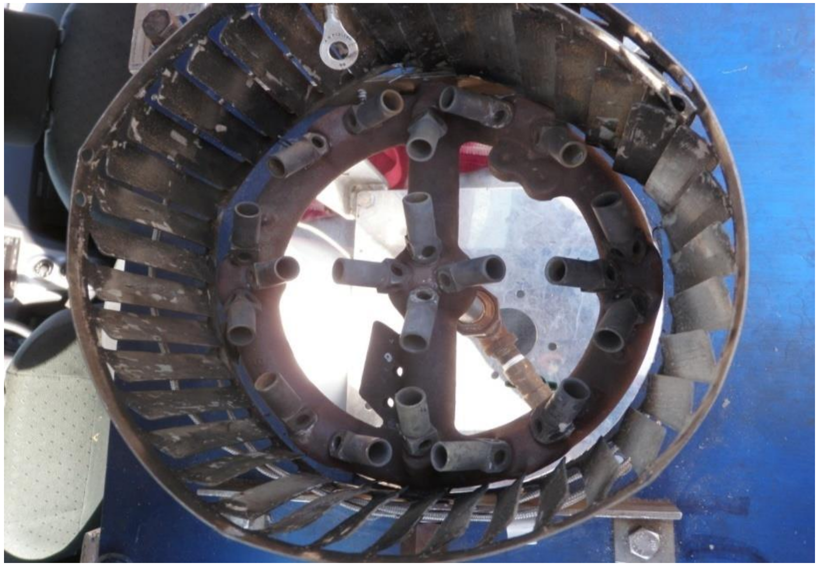
•Also siloxanes are being recognized as requiring attention.

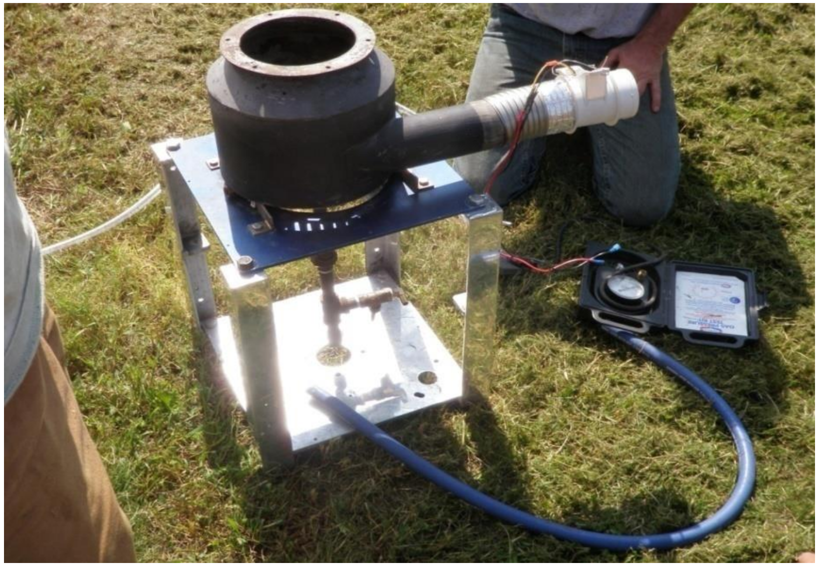
1 kW requires about 25 cu ft biogas

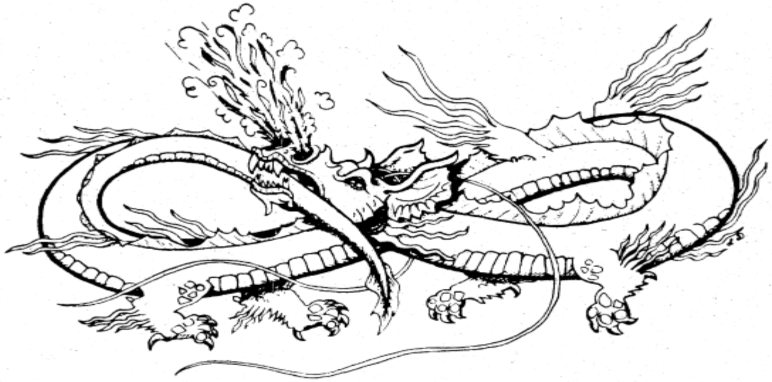
A huge expense for smaller systems

China – miscellaneous mobile and engine biogas applications

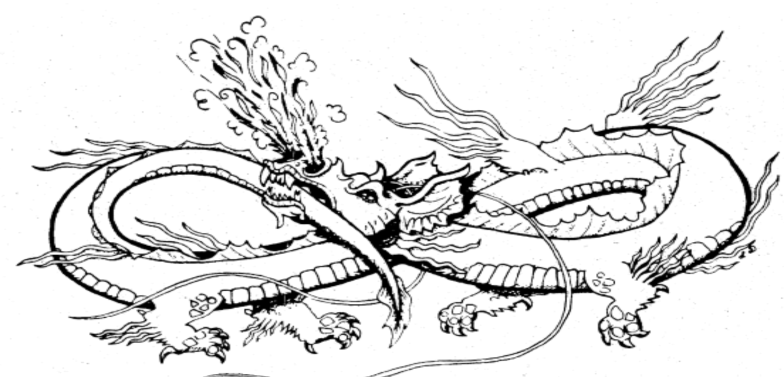
Ring burner with steam generator
External combustion for electricity generation



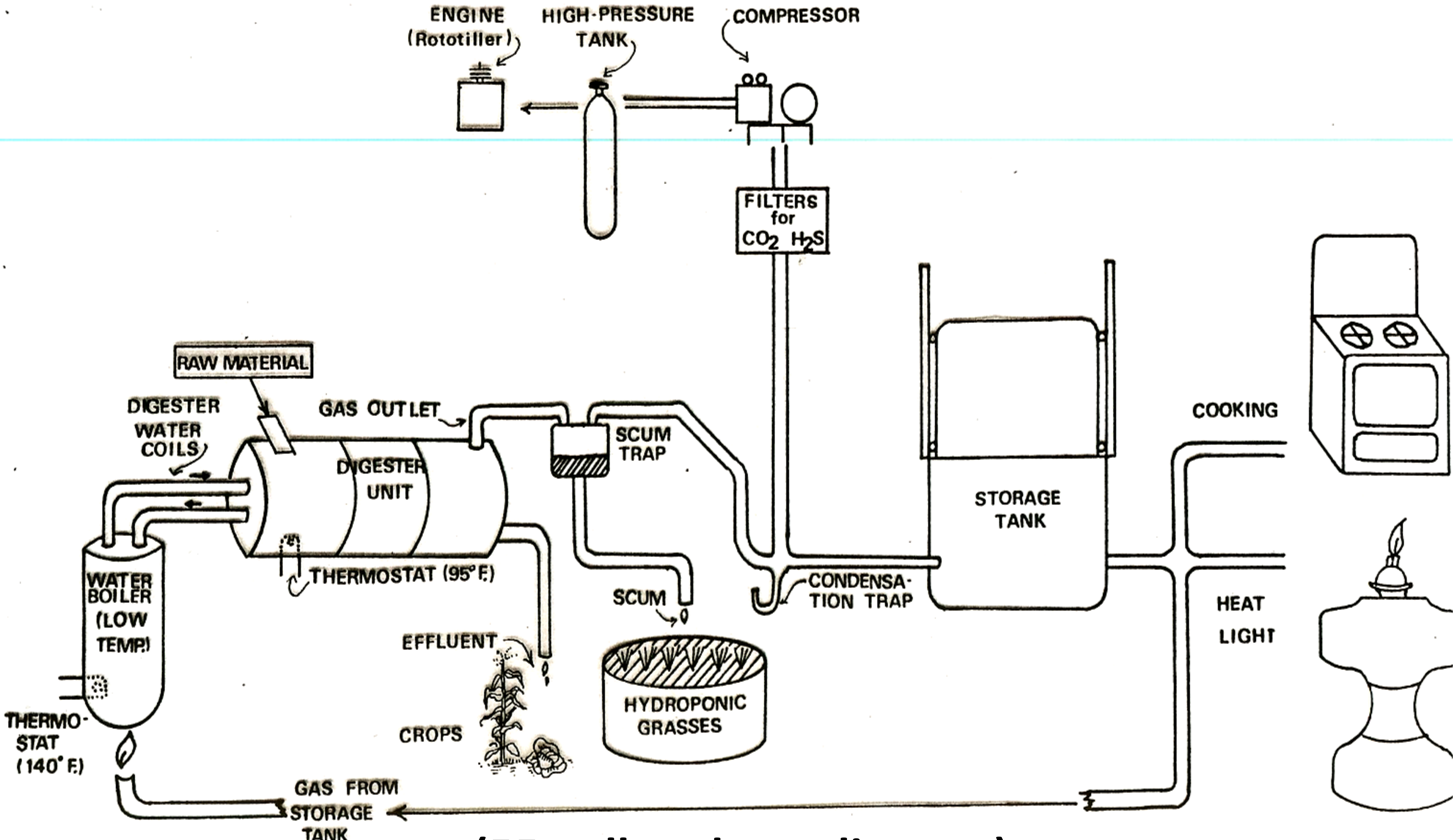




SYMBIOTICALLY INTEGRATED SYSTEMS



Integrated Digester Systems



(55-gallon drum digester)

NOTE: 1 55-gal drum contains 7.3 cu ft
One stove burner on high may use >16 cu ft/hour

Integrated Digester Systems
(China)

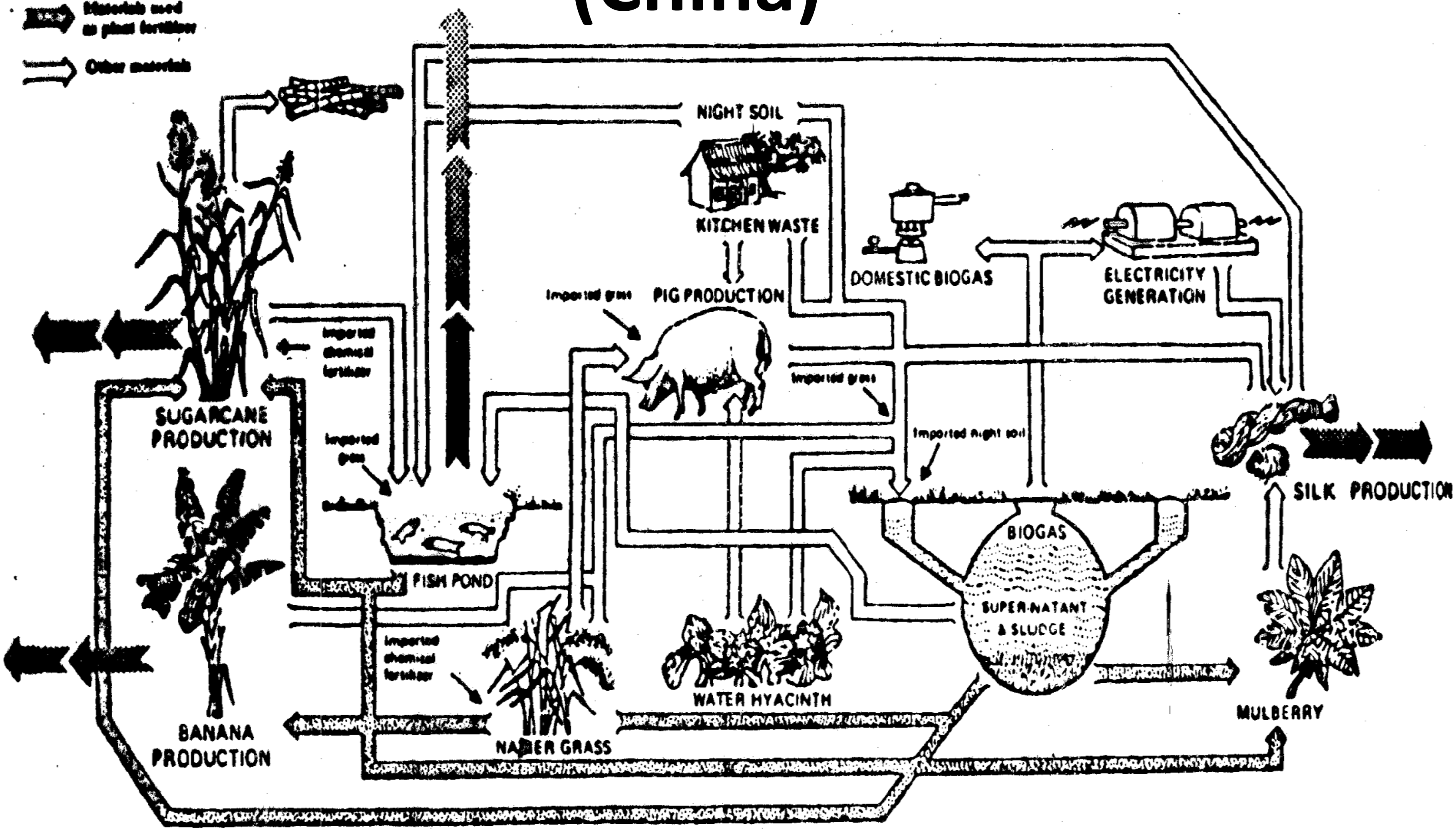
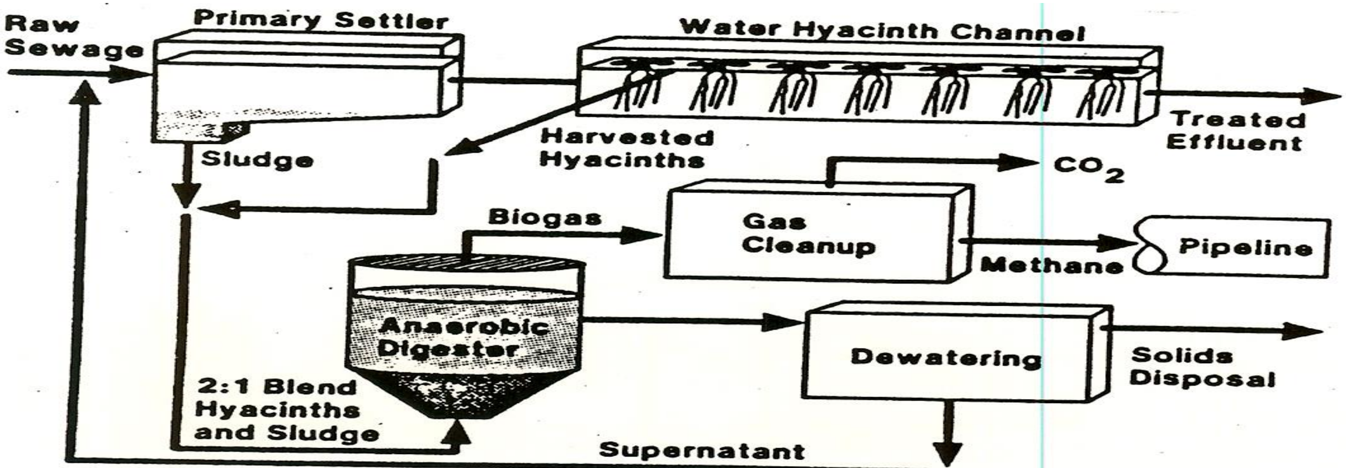
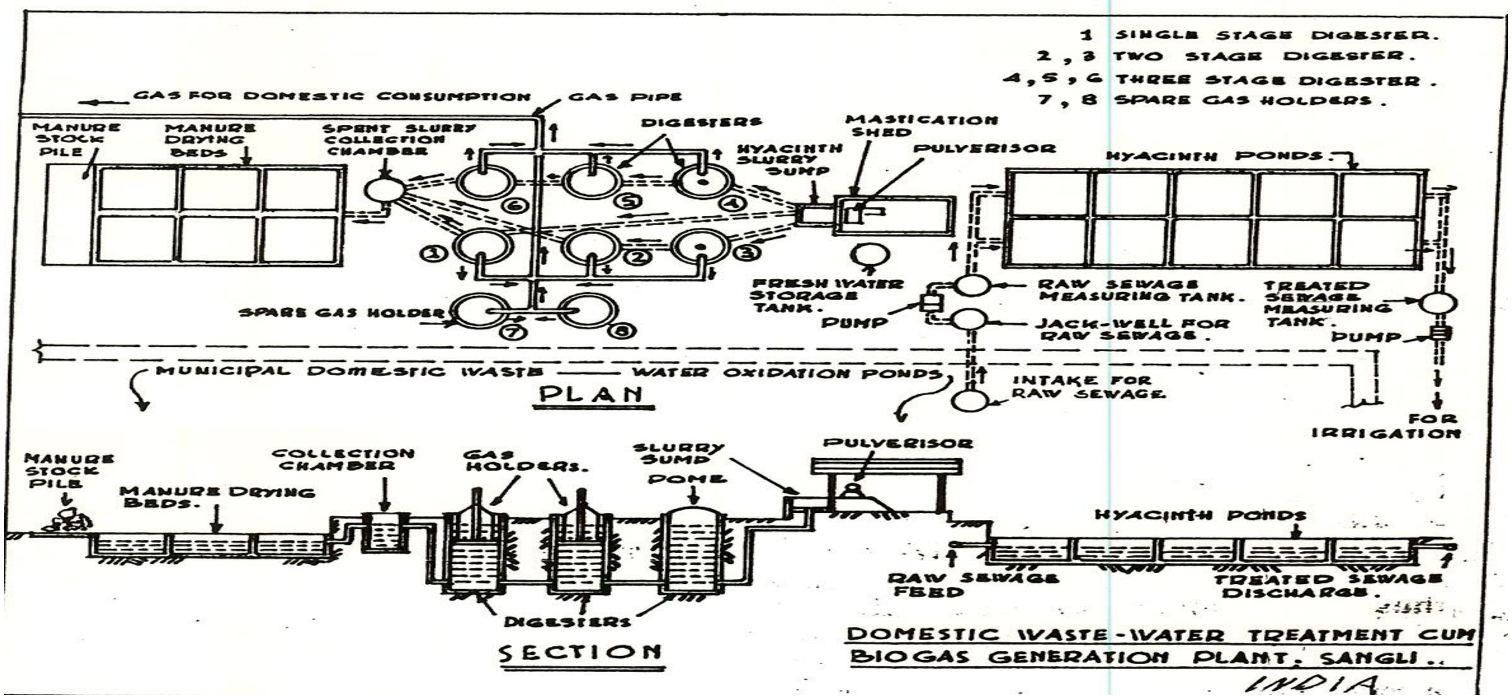


FIGURE 6.17 Fish, pigs, sugarcane, bananas, and silk are produced on this integrated farm in rural China. (*Development Forum*)

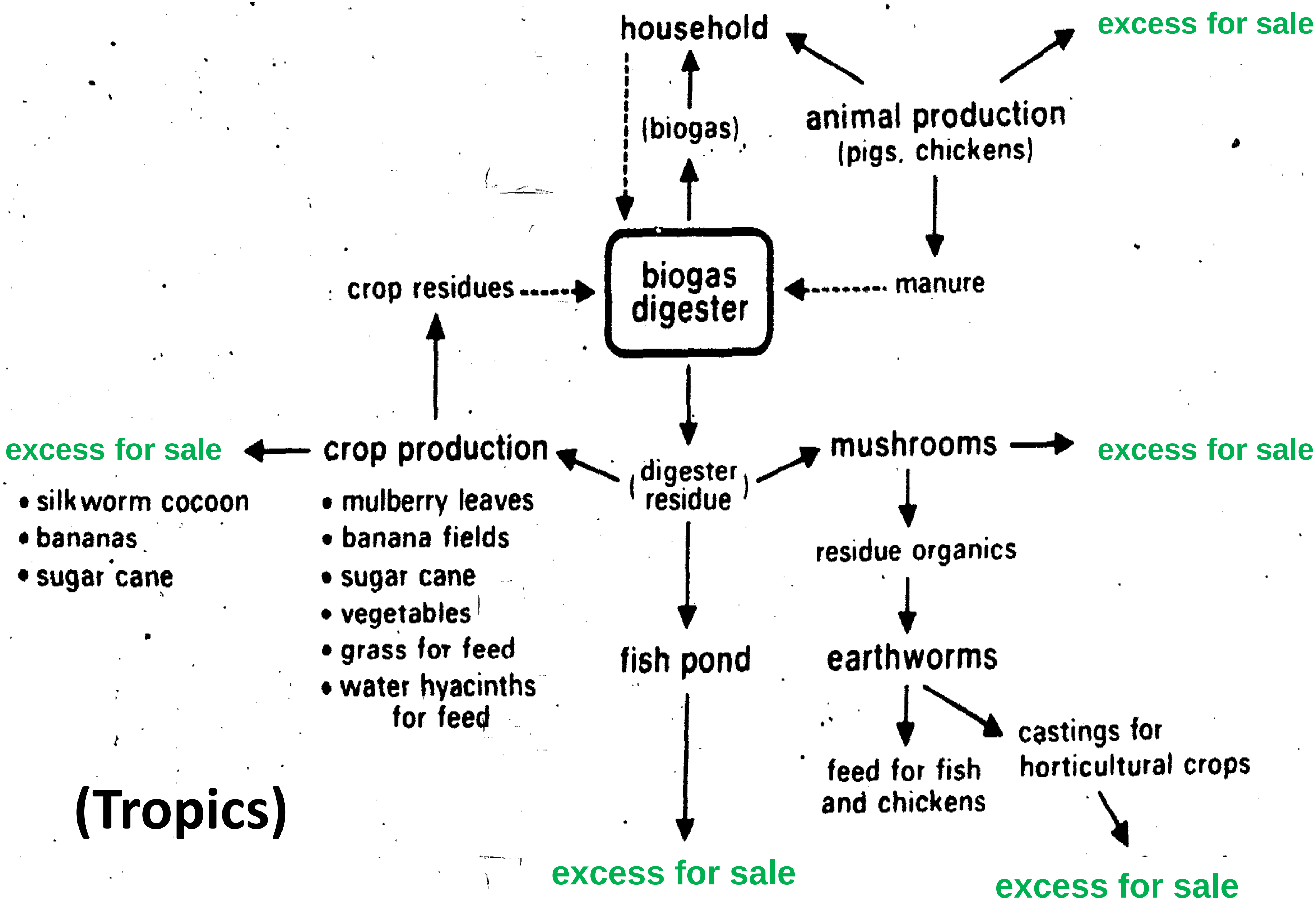
Integrated Digester Systems



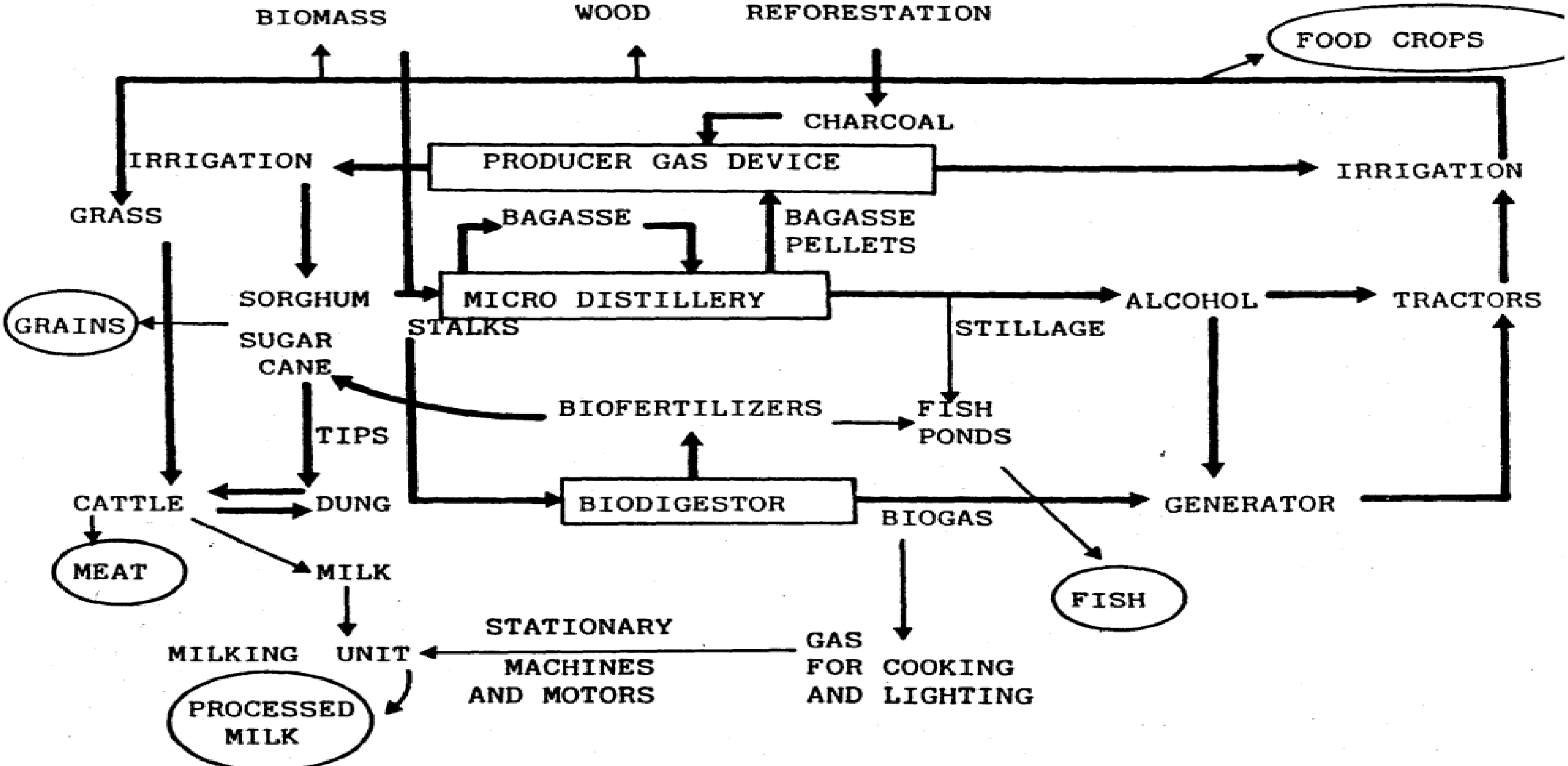
(Sewage Treatment)



Integrated Digester Systems



Integrated Digester Systems



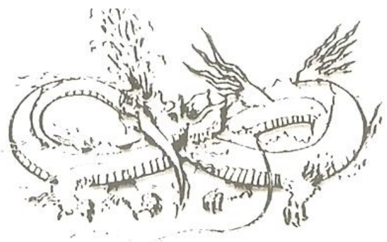
(Brazil)

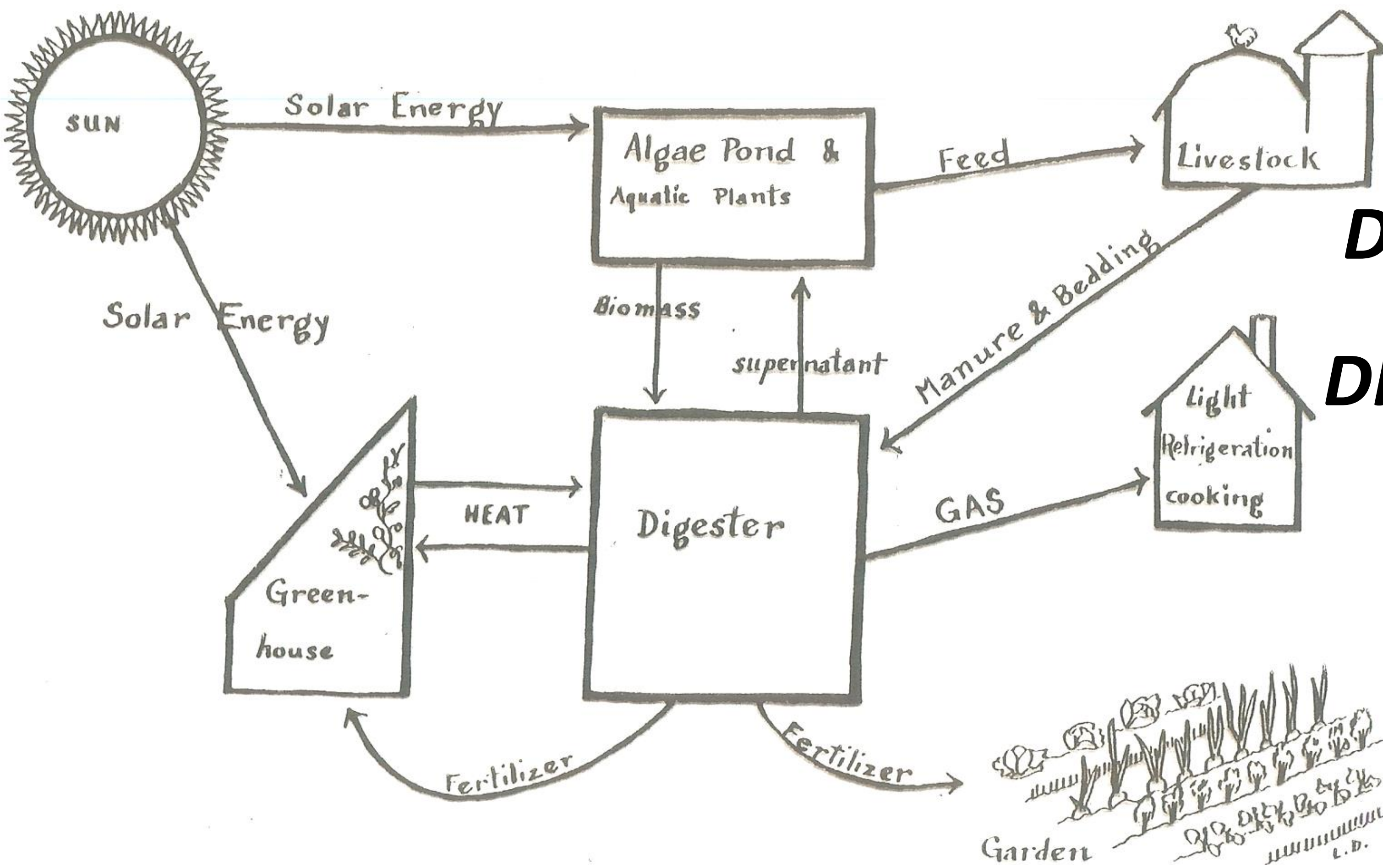
Note : Thick lines and arrows indicate main interlinkages between energy elements of the integrated system.

FISH : increased or new food output.

Integrated Digester Systems

West Virginia, 1979-82

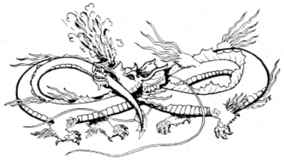


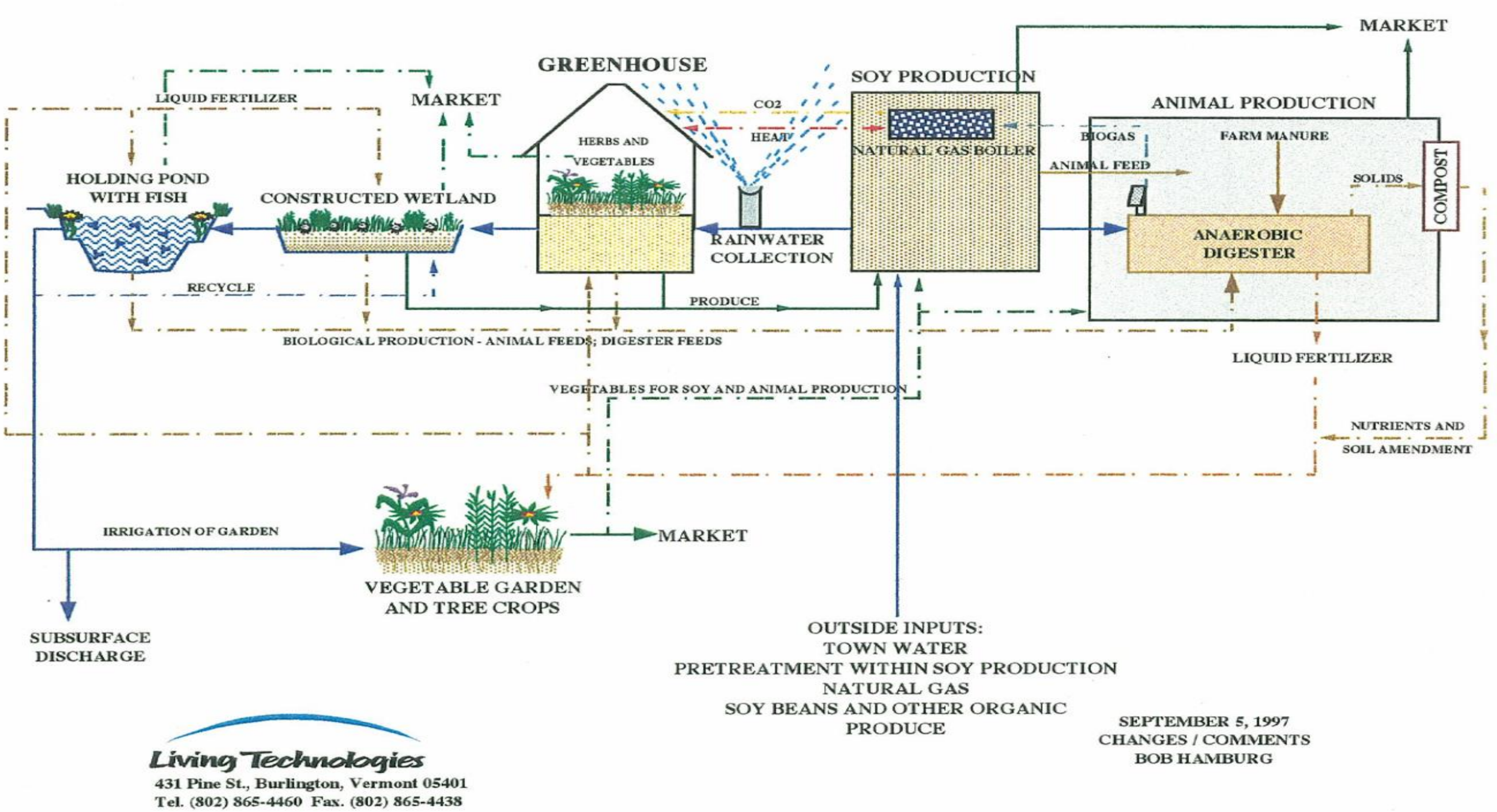


DRACO I
and
DRACO II

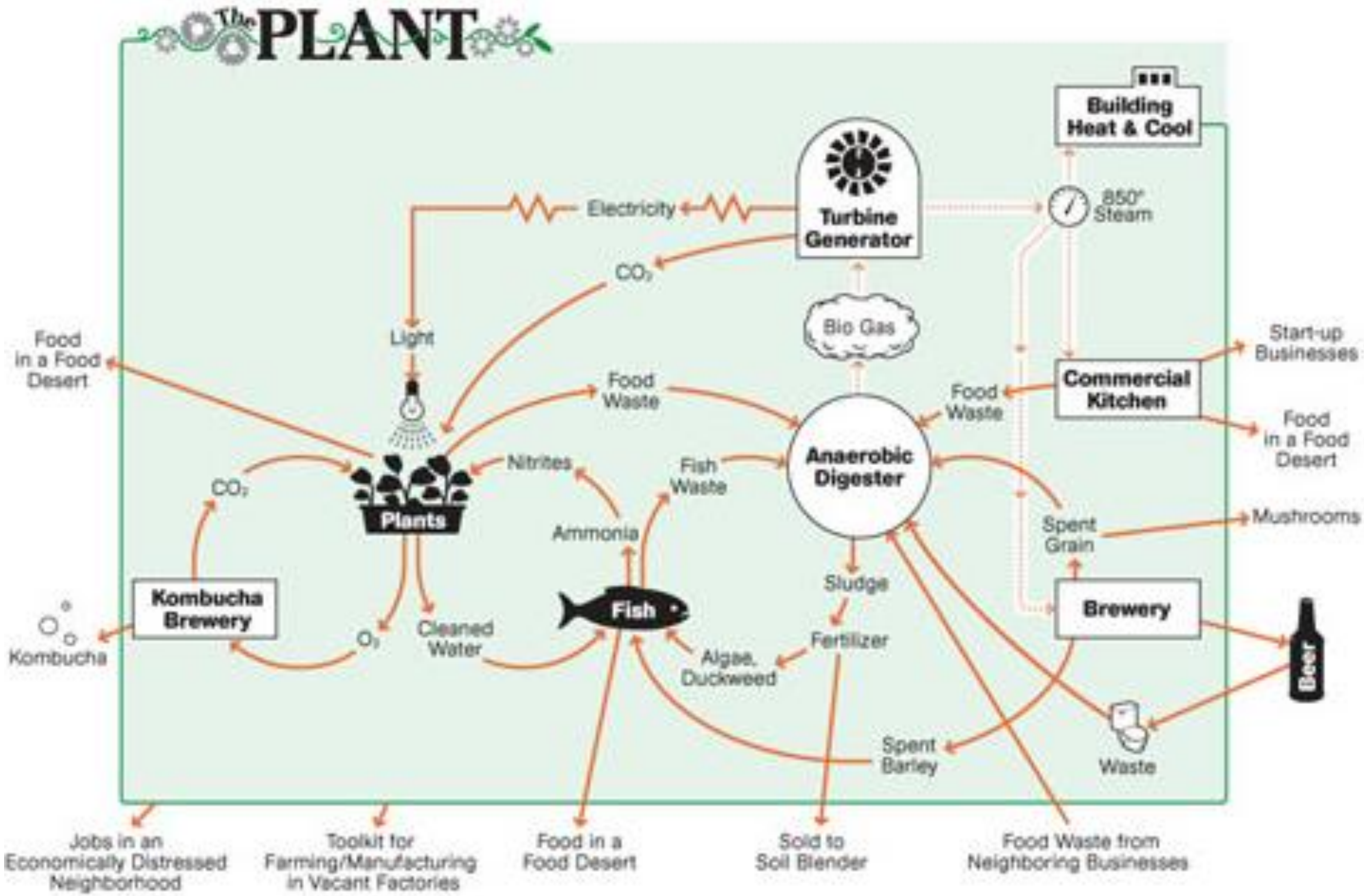
Integrated Digester Systems

Expansion of organic tofu and soy-based products enterprise – Central West Virginia



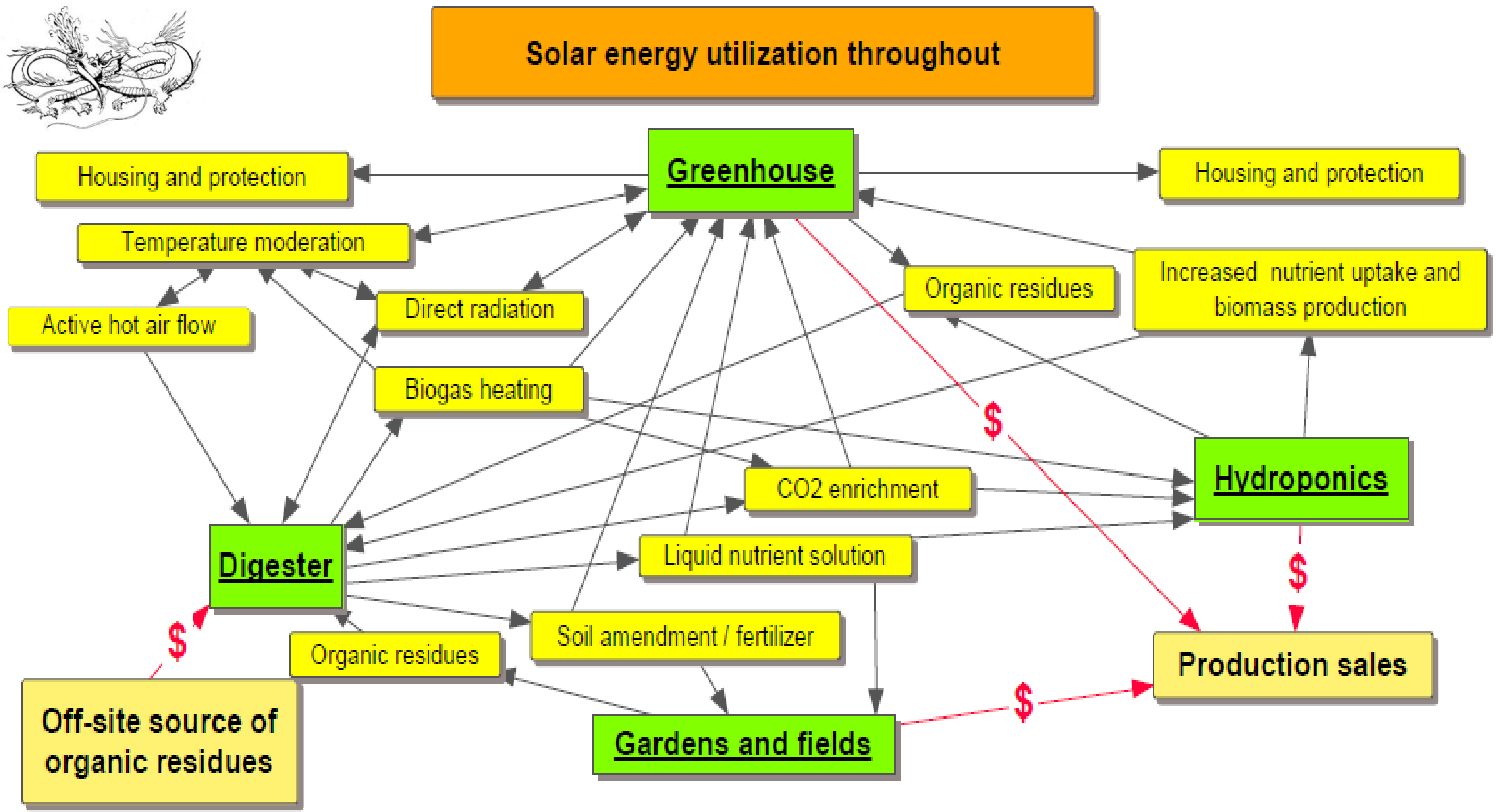


Integrated Systems -- Currently happening in Chicago!



Integrated Digester Systems

Greenhouse -- Digester -- Hydroponic/Aquaponic System Symbioses



Thermal Mass for Greenhouse Temperature Maintenance

Draco II – first spring in the greenhouse

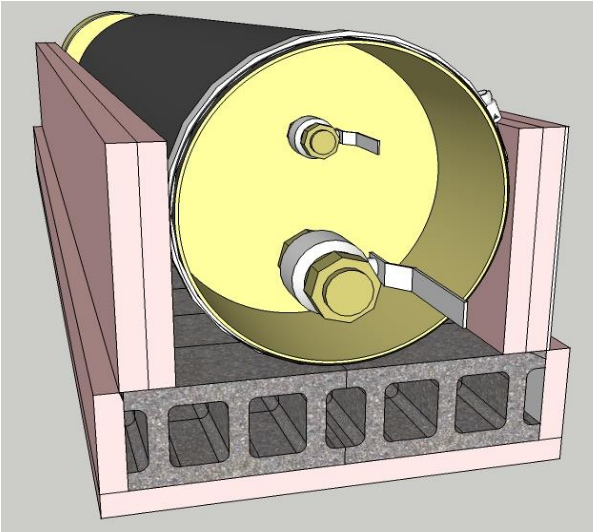
Water Barrels….

Why not Digesters?

500-gal batch digesters?

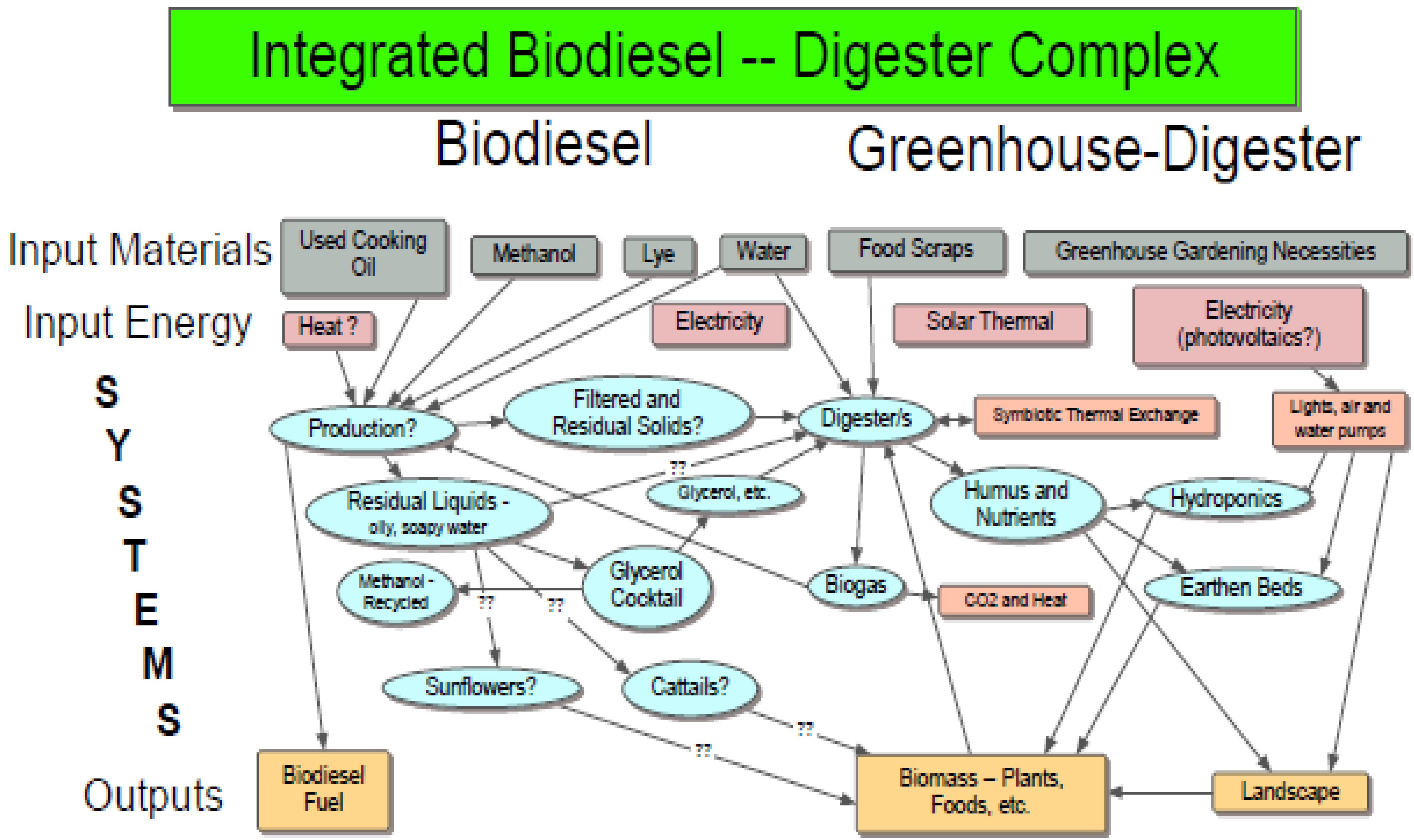
Partially buried sausage digesters and gas storage beneath growing tables in a greenhouse

Block beneath digester can provide mass and channels for photovoltaic forced hot air from greenhouse ceiling



Hydroponics and/or aquaponics can substitute for soil-based growing tables

Integrated Digester Systems



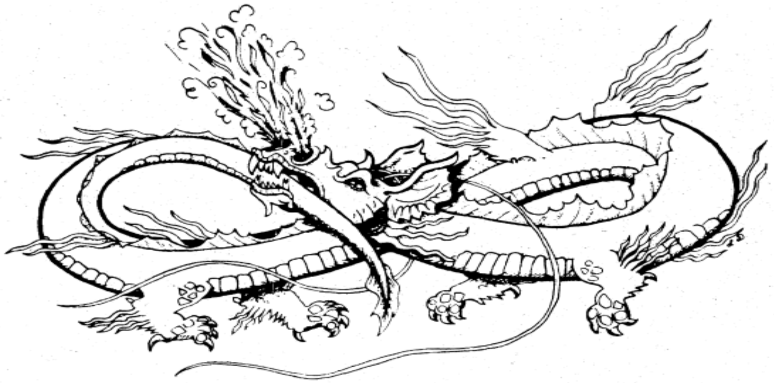
Economic Appraisal of Integrated Digester System Components

(India, ~1990)

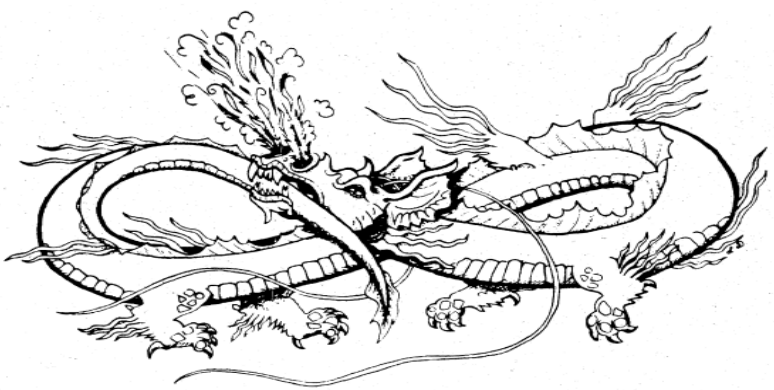
Component	Unit Price (Rs)*	Value of Product (Rs)	Percentage of System
Biogas (petrol equivalent 1.62 m^3=1 liter)	13.5	2025	13%
Fish (kg)	20	3000	20
Duck (kg)	25	3750	25
Algae (kg) (40% protein)	08	4000	26
Agricultural produce (kg)	05	2500	16

* 1 US$ = Rs 26

“External” Benefits, i.e. unvalued in most economic analyses – Sanitation; Reduced air pollution and other respiratory health-related benefits; Agricultural nutrient conservation; Avoided costs of fossil fuels; and Greenhouse-gas neutrality



DIGESTER EFFLUENT UTILIZATION



Kilby Farm Duckweed Pond with solar-powered collection boat

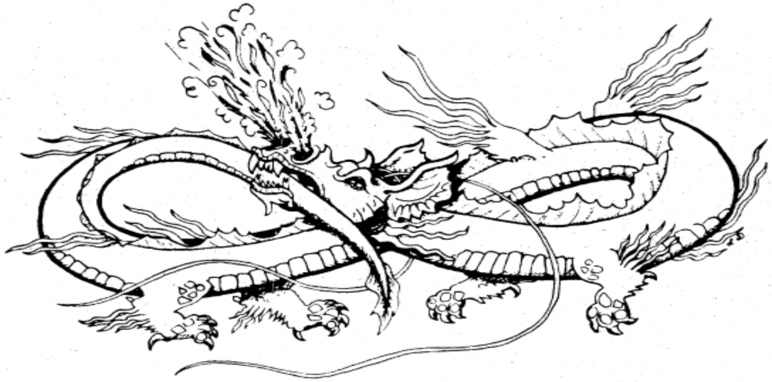
500 lbs. per day collected in warmer seasons

Draco I – pond growth

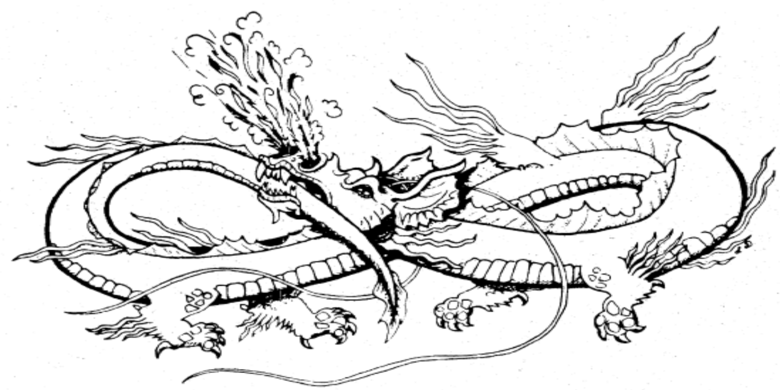
Aquatic growth can be up to 5 times more efficient at conversion of solar energy to biomass.

Water hyacinth

Algae – hard to harvest, but digestible



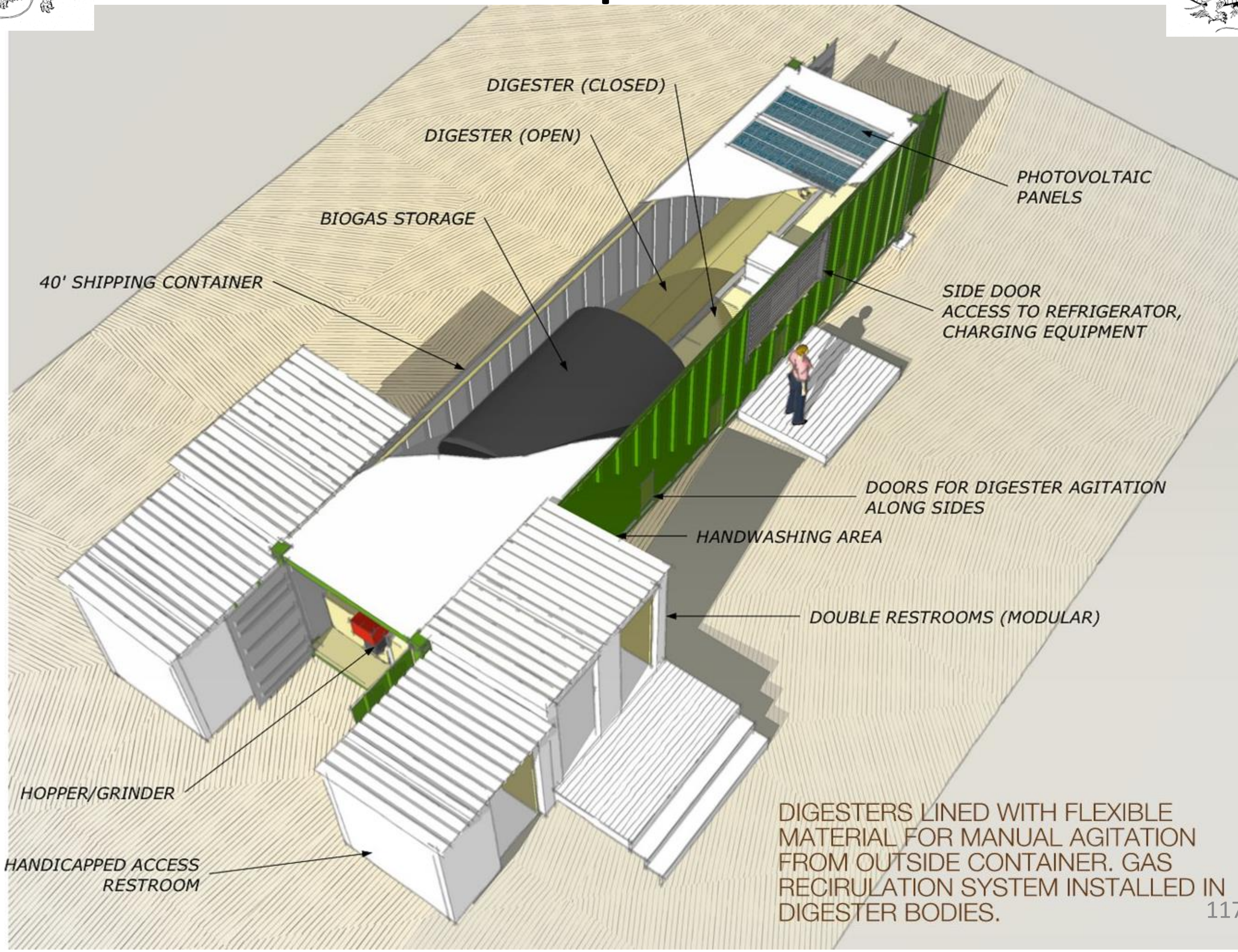
OTHER POSSIBILITIES: Further ruminations



Greenhouse—digester system for an Elementary School

Energy Independent!

Container—Digester as a Community Develop Module

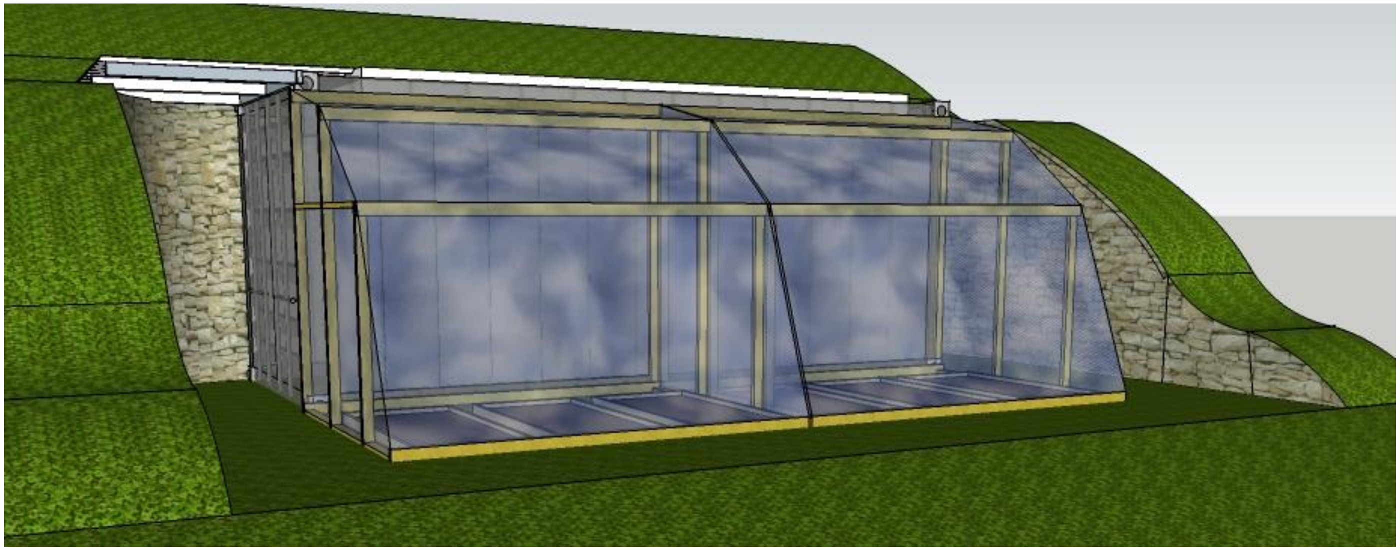


Container-Digester
Community Infrastructure Potential

- **Sanitation** – Toilet facilities and residue management for more than 200 people (through AD)
- **Fuel Supply** – 10-15+ cubic meters of biogas/day; potential for community kitchens (biogas)
- **Refrigerator/Freezer** – Small unit for medicines and other community necessities (biogas-fueled)
- **Water Supply** – Rain collection and storage from nearly 17 square meters roofing
- **Hand Washing Facilities** – As well as a potential shower facility
- **Community Battery Charging Station** – Powered by photovoltaics
- **Area Lighting** – Around the facility powered by photovoltaics
- **Agricultural Inputs** -- High-nutrient liquid for plant fertilization and excellent humus for soil improvement
- Others?

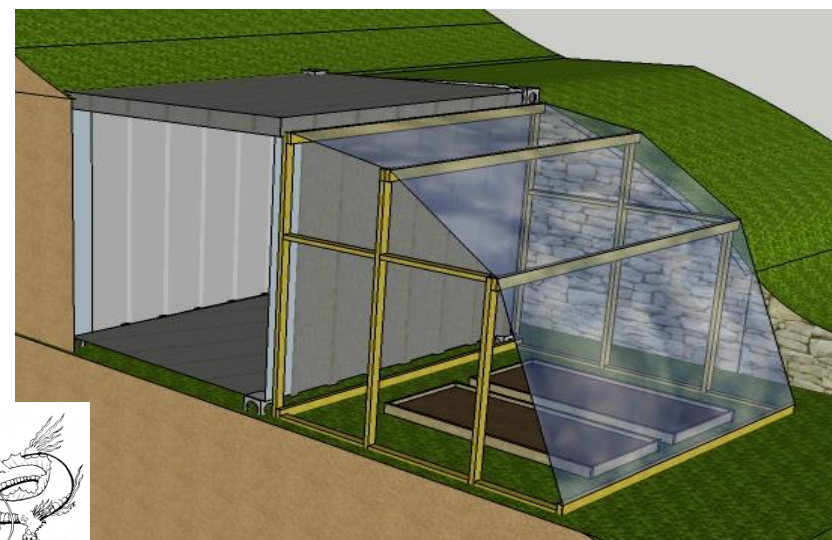
Ah the irony

SHIPPING CONTAINERS – The wastes of misguided globalization as a resource for increased self-reliance.



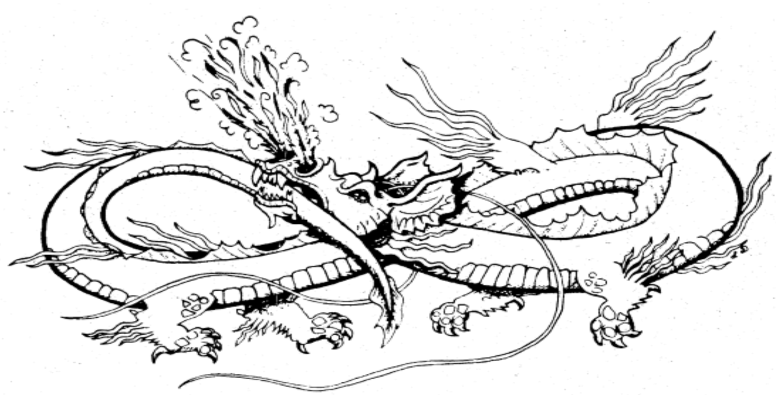
Containers are currently being marketed in England as digester modules for equestrian centers (BioCycle, '14)

20'- and 40' earth-bermed containers may be adapted to provide both a digester body and structural components for greenhouses, etc.



Take homes

Biogas systems are an integral part of a regenerative future



BENEFITS OF BIOGAS SYSTEMS

- **NUTRIENT CONSERVATION**
  ALL nutrients going into a digester are available in the effluents (except for a small amount of sulfur released as H_2S, and some N_2 if digester feed is unbalanced), thus providing a full spectrum of plant nutrients and reducing or eliminating the need for chemical fertilizer input.
- **SOIL REGENERATION**
  Organic carbon compounds in the effluents increase the humic content of agricultural soils.
- **SANITATION**
  When allowed to go toward completion, anaerobic digestion results in total destruction of most disease vectors which may have been present in the feed materials; nearly total destruction of most of those remaining; and very significant destruction of the most recalcitrant (including ascaris and other eggs). Also, the digestion process does not result in any new pathogen vectors.
- **PROVISION OF NATURAL GAS**
  With minor adjustments, biogas (generally 65 % CH_4, 35 % CO_2, and traces of others) can be used in any way fossil gas is used.
- **REDUCTION OF INDOOR AIR POLLUTION AND RESPIRATORY PROBLEMS**
  Pollutant emissions from combustion of biogas are similar to those from burning fossil gas. When biogas is used to replace biomass or coal as a cooking fuel, indoor air pollution and related health problems are greatly reduced.
- **ODOR CONTROL**
  Volatile solids (what we smell) are consumed by digestion.
- **FLIES AND RODENTS NOT ATTRACTED TO DIGESTER EFFLUENTS**
- **REDUCED VIABILITY OF WEED SEEDS AFTER DIGESTION**

The most pollution-free option for sustainable utilization of biomass energy!

The means to most closely approach the ideal of carbon neutrality!

NATURAL GAS WITHOUT FRACKING

THE ECONOMICS OF NATURAL GAS SOURCES

FOSSIL GAS - MARCELLUS OR WHEREVER	RENEWABLE GAS - ORGANIC RESIDUE-GENERATED

BOTH HAVE CAPITAL, DEVELOPMENT, INFRASTRUCTURE, OPERATING AND MAINTENANCE COSTS

THE DIFFERENCE LIES IN THE EXTERNALITIES

Environmental Degeneration	Environmental Regeneration
Water contamination -- from exploitation, fracking, distribution, use, etc.	Water sanitization, conservation, and productive use, etc.
Air contamination -- from exploitation, fracking, distribution, use, etc,	Air de-contamination -- from odor control, replacement of fossil and less-efficient biomass fuels, carbon sequestration, etc.
Soil ecosystem contamination and destruction	Soil ecosystem regeneration and maintenance - increasing humus and carbon sequestration [and production potential]
A source of nitrogen fertilizers, explosives, etc.	Total conservation of nutrients for local re-growth
Dependent on highly subsidized transportation	Local management, production, and distribution
Centralized Control	Local Self-reliance
Increasing atmosphereic carbon load	Carbon sequestration and recirculation
Any enviromental tax liabilities	Any environmental and carbon tax credits

Please!

Recognize that, if you choose to investigate some of the possibilities for biogas systems, you will be producing a greenhouse gas which is 1-2 orders of magnitude stronger than carbon dioxide. You must take full responsibility for its combustion before dispersal.

Notes on further information:

I am an IT ignoramus. but I recognize that the web includes a virtually infinite amount of verbiage, videos and shared information and experiences with this on-going process. Since I occasionally find very interesting and useful ideas, techniques and pieces in the oddest places, I hesitate to narrow anyone's investigations. One can begin by googling "biogas" and probably never get to an end.

I would suggest looking into websites related to: The USDA AgStar Program and the American Biogas Council for introductory information primarily about large-scale systems; GATE, Germany's International Aid Agency; and SNV, The Netherland's International Aid Agency.

There are a great many academic tomes on the bio-chemistry of anaerobic digestion but David House's Biogas Handbook is certainly the most understandable and reasonably priced that I know.

After considerable consideration, I have chosen to postpone a contracted book, *The Why and Wherefore of Biogas Systems*, and to first pursue establishment a DragonHusbandry.com website. I intend for this site to ultimately include all of the information which would have been included in the book, plus the opportunity for extensive information exchange among smaller-scale digestion system practitioners.

Bob Hamburg, Omega-Alpha Recycling Systems
Email: bhanomalous7@gmail.com Current website: omega-alpharecycling.com

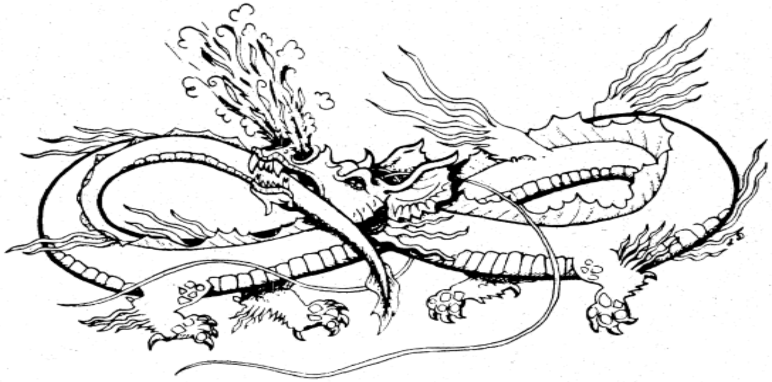
A few thoughts from one of the 20th Century's most revered scientist.

The most beautiful experience we can have is the mysterious…the fundamental emotion which stands at the cradle of true art and true science.

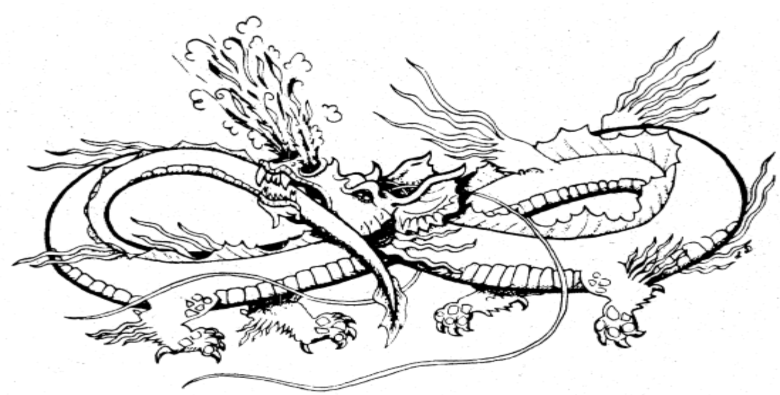
I assert that the cosmic religious experience is the strongest and noblest driving source behind scientific research.

When I examine myself and my methods of thought, I come close to the conclusion that the gift of fantasy has meant more to me than my talent for absorbing positive knowledge.

Albert Einstein



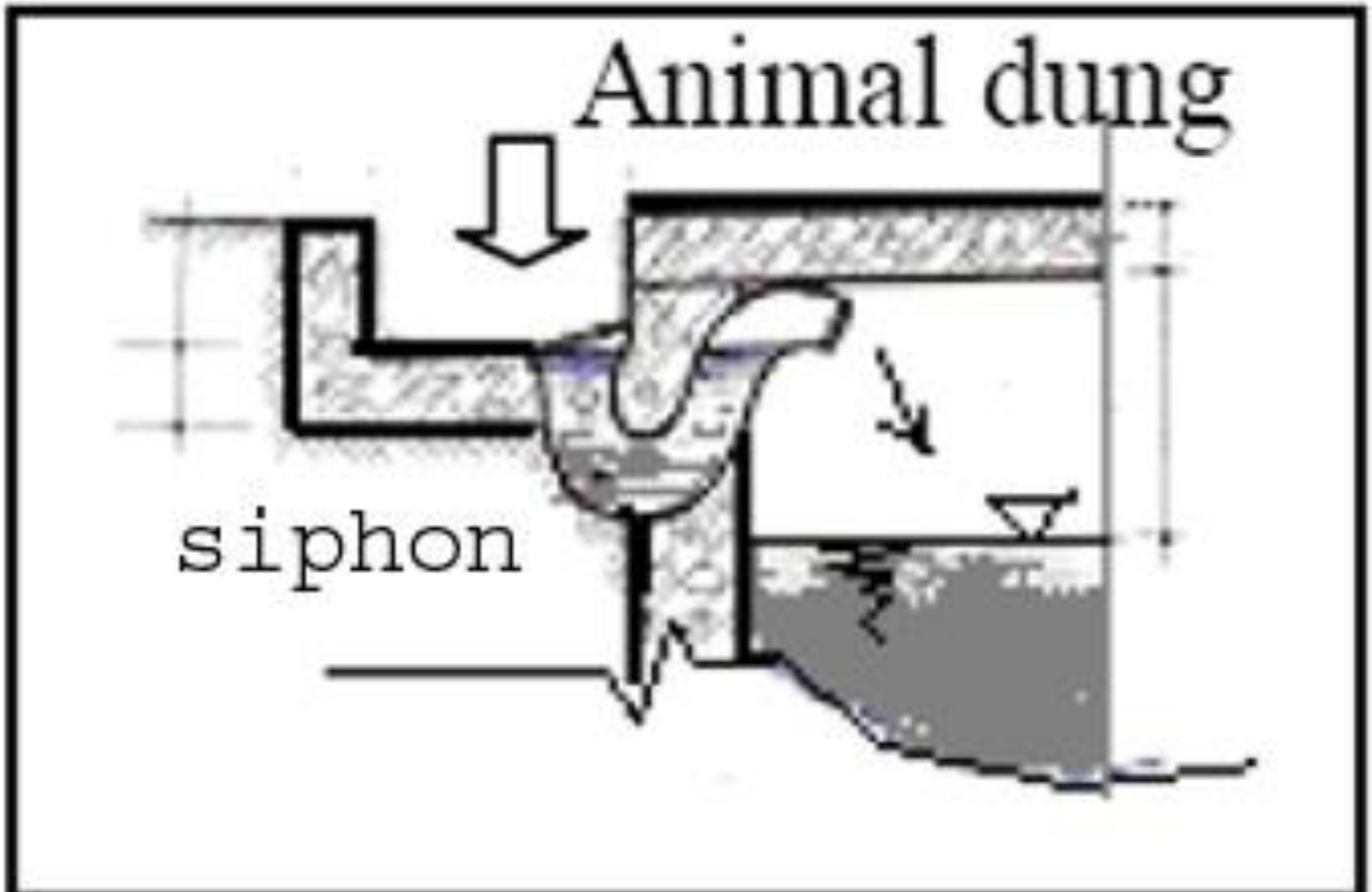
EPILOGUE, misc.



China – extra-long, double-forked, twist-lock digester cleaning fork

History – a viable, low-tech, high-flow valve, ~1978

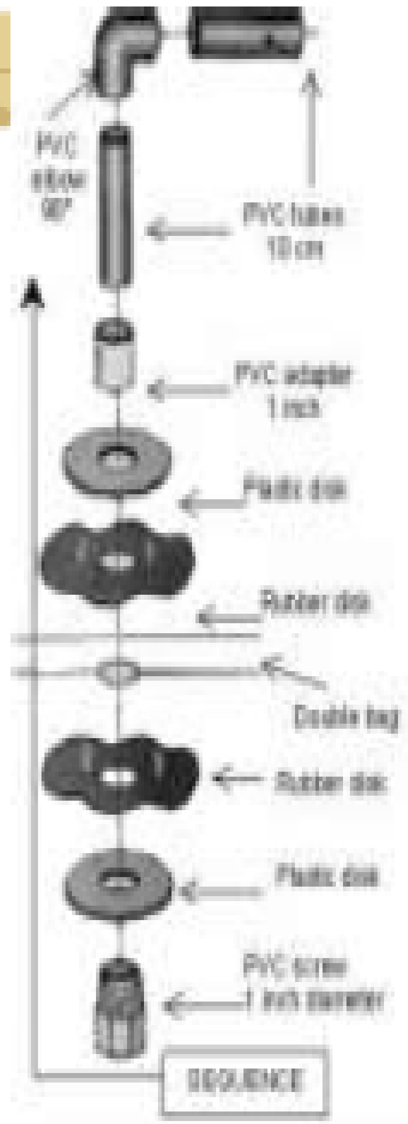
Standard drain gas trap

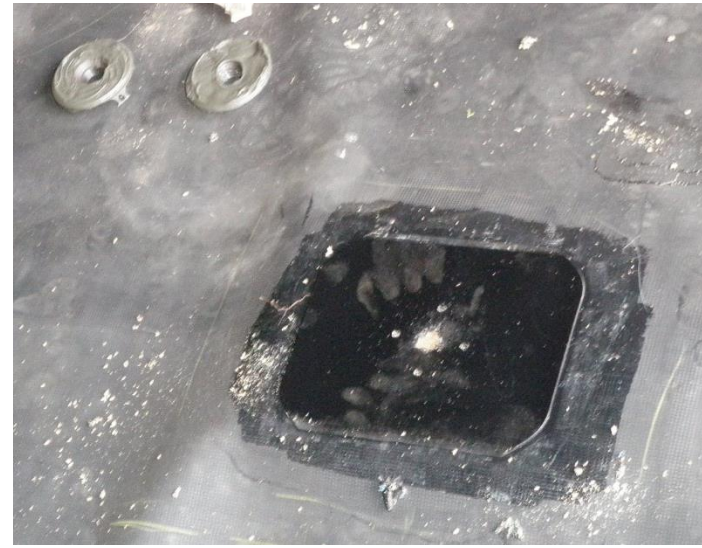


Sausage digester port construction

Gas line

- These parts make up a "through-the-wall" gas line for a "traditional" plastic bag digester
- Some of these parts are relatively much more expensive: the threaded parts and the elbow, for example...

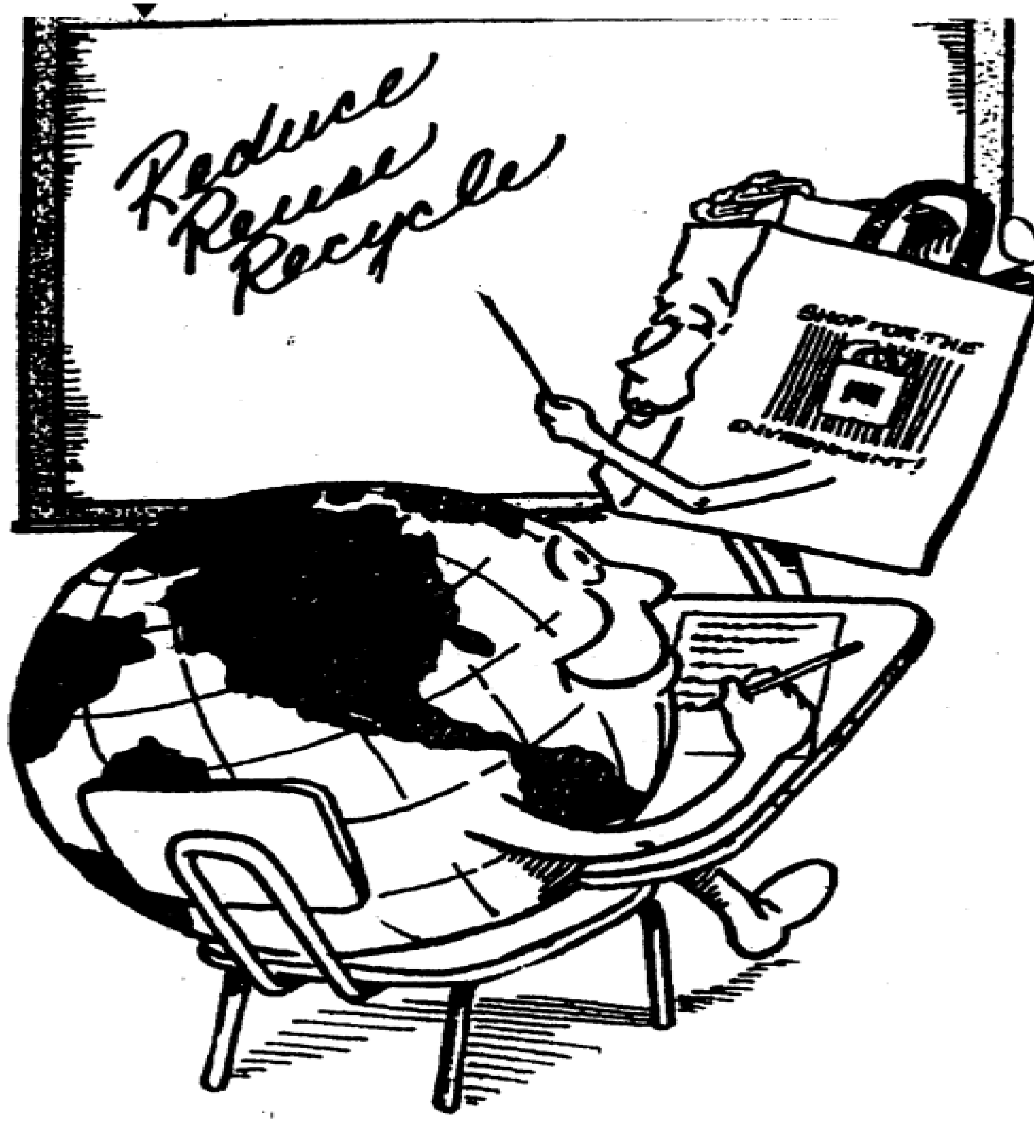




Flanges for Dickinson EPDM digesters

Shop for the environment?

What is WRONG with this Picture!



Who needs to learn from whom?