

# sewers & scientific thought

## **Nineteenth Century: Miasmatic Theory**

In the 1850s sewers were state-of-the-art. At this time the predominant understanding of illness was miasmatic theory—the idea that disease was caused by foul or corrupt air—a legacy of Greek and Medieval medical thought, passed down from Hippocrates and Galen to Renaissance and Enlightenment thinkers [1]. The solution to the sanitary problems of burgeoning cities, according to miasmatic theory, was to prevent bad air by evacuating waste from the city and diluting it in running water [2]. The sewers of Paris and London, marvels of nineteenth-century engineering, promised to clean the city by dumping raw sewage into their waterways.

Germ theory, developed by Louis Pasteur in the 1860s and Robert Koch in the 1870s, cast doubt on this strategy. Outbreaks of cholera in London were linked, controversially, to waterborne illness by Dr. John Snow in the 1849. But by the time germ theory gained wide acceptance, sewer systems had already been constructed in most European and American cities.

## **Twentieth Century: Germ Theory**

The sewers, rooted in miasmatic theory, made no distinction between wastewater and stormwater (based upon the mistaken belief that once waste was diluted it was effectively treated); thus retrofitting the sewers proved difficult. The germ-theory-inspired waste treatment facilities, affixed like filters to the end of the pipe, assuaged the worst of the human health concerns, but were not sized for major rain events. Today, major North American cities from Vancouver to Cincinnati regularly discharge sewage into local waterways [3]—a legacy we owe, ultimately, to miasmatic theory.

## **Twenty-first Century: Biology & Ecology**

Since the installation of sewage treatment facilities, biological and ecological sciences have continued to illuminate the myriad effects of sewage—even treated sewage—on human and ecological health. PCBs, endocrine disruptors, heavy metals, and phosphates are routinely discharged into waterways, with

mounting negative consequences [4]. Treatment facilities—rooted in the science of germ theory—were not designed to remove these contaminants.

What is the waste system that will be inspired by the new science of ecology? Can it be applied as a band-aid fix to existing infrastructure—that lingering built expression of Medieval science? Or does it require something else entirely?

Architect William McDonough and chemist Michael Braungart propose a cradle-to-cradle paradigm in which “waste equals food,” flows are cyclical, and toxins are designed out of the system from the outset [5]. This paradigm recognizes both the human health impacts illuminated by germ theory and ecological understanding of the twenty-first century. What will a no-waste, 100% good, cradle-to-cradle waste system look like? This is our challenge.

[1] John M. Last, “Miasma Theory,” *Encyclopedia of Public Health*, ed. Lester Breslow (New York: Macmillan Reference, 2001), 765. For a discussion of the intellectual lineage of 19th-century sewers, see Rebecca Williamson, *The Breath of Cities*, in *Aeolian Winds and the Spirit in Renaissance Architecture*, ed. Barbara Kenda (London: Routledge, 2006).

[2] Carlo M. Cipolla, *Fighting the Plague in Seventeenth-Century Italy* (Madison: University of Wisconsin Press, 1981). See also Leon Battista Alberti’s *On the Art of Building in Ten Books* (1450), which was oft cited by Enlightenment thinkers.

[3] Elaine MacDonald, *The Great Lakes Sewage Report Card* (Canada: Sierra Legal, 2006). [www.sierralegal.org](http://www.sierralegal.org)

[reports/great.lakes.sewage.report.nov.2006b.pdf](http://reports/great.lakes.sewage.report.nov.2006b.pdf).

[4] Graeme Wynn, Graeme. *Risk and Responsibility in a Waste-Full World*, forward to *The Culture of Flushing*, by Jamie Benidickson (Vancouver: UBC Press, 2007).

[5] William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way we Make Things* (New York: North Point Press, 2002).

# biodigester primer

## What is a biodigester?

It is a vessel or container which is utilized to facilitate an environment conducive for anaerobic digestion of organic wastes into biogas and a nutrient rich, pathogen-free digestate which can be used as fertilizer. Biodigestion has been used all over the world in a variety of contexts ranging from household sized systems [1] to large commercial and municipal scale treatment [2, 3]. The versatility, scalability, productivity and new European government policies have caused an increase in the adoption of this technology [4].

## What is biogas?

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of biofuel.

One type of biogas is produced by anaerobic digestion of biodegradable materials such as biomass, manure or sewage, municipal waste and energy crops. This type of biogas comprises primarily methane and carbon dioxide. The gases methane, hydrogen and

carbon monoxide can be combusted or oxidized with oxygen. Air contains 21% oxygen. This energy release allows biogas to be used as a fuel. Biogas can be used as a low-cost fuel in any country for any heating purpose, such as cooking. It can also be used in modern waste management facilities where it can be used to run any type of heat engine, to generate either mechanical or electrical power. Biogas can be compressed, much like natural gas, and used to power motor vehicles and in the UK for example is estimated to have the potential to replace around 17% of vehicle fuel. Biogas is a renewable fuel, so it qualifies for renewable energy subsidies in some parts of the world [5].

Typical composition of biogas [6]

Compound	Chem	%
Methane	CH <sub>4</sub>	50-75
Carbon dioxide	CO <sub>2</sub>	25-50
Nitrogen	N <sub>2</sub>	0-10
Hydrogen	H <sub>2</sub>	0-1
Hydrogen sulfide	H <sub>2</sub> S	0-1
Oxygen	O <sub>2</sub>	0-2

The composition of biogas varies depending on the organic material being digested and varies other

factors including temperature, pH and pressure. Pure methane has a calorific value of 9,100 kcal/m<sup>3</sup> at 15.5°C and 1 atmosphere; the calorific value of biogas varies from 4,800 - 6,900 kcal/m<sup>3</sup>. In terms of energy equivalents, 1.33 - 1.87, and 1.5 - 2.1 m<sup>3</sup> of biogas are equivalent to one litre of gasoline and diesel fuel, respectively [7].

## What is digestate?

The digestate produced by anaerobic digestion is nutrient-rich and pathogen-free slurry which can be used as a soil conditioner for crops or, in some cases, animal feed. Acidogenesis and methanogenesis occurring during anaerobic digestion create the digestate and give it its fibrous and high quantities of nitrogen and phosphorous, respectively.

In addition to being nutrient-rich, digestate from operating anaerobic digestion plants have passed the standard for "Exceptional Quality" as defined by US Environmental Protection Agency when being tested for elements of concern, suggesting it is a high-quality and safe fertilizer [8].

[1] <http://www.arti-india.org/>

[2] [http://www.organics-recycling.org.uk/index.php?option=com\\_content&view=article&id=447:qlarge-stq-ad-facility-gets-planning-permission&catid=1:latest-news&Itemid=18](http://www.organics-recycling.org.uk/index.php?option=com_content&view=article&id=447:qlarge-stq-ad-facility-gets-planning-permission&catid=1:latest-news&Itemid=18)

[3] <http://www.melbourne.vic.gov.au/info.cfm?top=171&pa=4112&pa2=4091&pg=4077#water>

[4] [http://www.anaerobic-digestion.com/html/brief\\_history\\_of\\_anaerobic\\_dig.html](http://www.anaerobic-digestion.com/html/brief_history_of_anaerobic_dig.html)

[5] [http://en.wikipedia.org/wiki/Biogas#cite\\_note-6](http://en.wikipedia.org/wiki/Biogas#cite_note-6)

[6] <http://www.kolumbus.fi/suomen.biokaasukeskus/en/enperus.html>

[7] Marchaim, Uri. Biogas Principles for Sustainable

Development. ISBN 92-5-103126-6. available online at: <http://www.fao.org/docrep/T0541E/T0541E00.htm#Contents>

[8] [http://www.alexmarshall.me.uk/index\\_files/documents/ResponseToConsultationonthesourcesegregationrequirementinParagraph7AofSchedule3totheWaste-Man.pdf](http://www.alexmarshall.me.uk/index_files/documents/ResponseToConsultationonthesourcesegregationrequirementinParagraph7AofSchedule3totheWaste-Man.pdf)

# policy considerations for biodigester development

A number of policies will improve the effectiveness of this biodigester program and/or leverage its effects in a positive way. To optimize the biodigestors, the goals must be to: (1) Increase the availability of carbon for proper biodigestion; (2) Manage stormwater to prevent disruptive overflows in combined sewers; (3) Mine the sewer to encourage water re-use; and (4) Spread the wealth to ensure maximum impact and job creation.

## **Goal 1: Increase the local availability of carbon for proper biodigestion**

1. Increase funding for street tree planting and maintenance.
2. Divert existing yard waste collection to the biodigestors, and provide on-site collection of yard waste, with compensation dependent on need.
3. Divert clippings from nearby parks to the biodigestors
4. Divert some cardboard and newspaper collection to the biodigestors, dependent on need.

## **Goal 2: Manage stormwater to prevent disruptive overflows**

1. Institute stormwater utility fees based on the costs of maintaining the stormwater infrastructure
2. Strategically invest some of the revenue in Low Impact Development projects including street trees,

bio-swales, permeable paving, rain gardens, and cisterns.

3. Retire or repurpose hard stormwater infrastructure as it becomes feasible.

## **Goal 3: Mine the sewer**

Sewer mining is the capture of sewage before or after treatment for re-use by a third party. Typical applications are for irrigation, though commercial and industrial uses have been found, even including potable drinking water. Australia, California, and Israel have been leaders in the legal and technological advances in this area.

A legal agreement is established between the sewer miner and the utility guaranteeing that a minimum flow will be maintained in the sewer line. Some arrangements allow free access and some require payment based on the cost of providing the waste water or on the replacement cost of getting comparable water elsewhere.

## **Goal 4: Spread the wealth**

The following policies deal with extending the positive impact of the biodigester program throughout the community.

A biodigester program creates new opportunities for the community:

1. Quality, inexpensive compost will be available at biodigester locations.

2. Inexpensive irrigation-quality water will be available for multiple uses.
3. Costly sewer upgrades and compliance costs will be diminished.
4. Stream quality will be improved, providing superior aesthetic, recreational, commercial, and environmental resources.
5. Public spending will shift from costly infrastructure to green collar jobs.
6. New business opportunities will be created around biodigesters and their outputs.

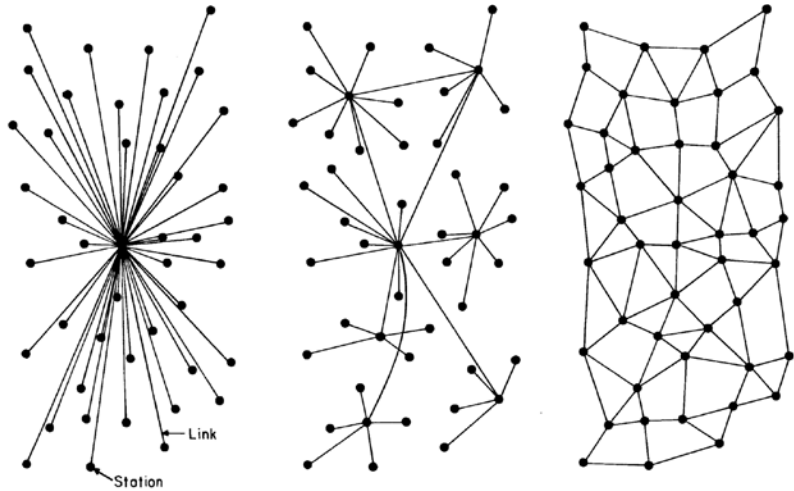
These opportunities can be matched with policies to extend and improve their effects:

1. Urban farming, gardening, and tree planting programs to make good use of the compost.
2. Economic development programs to promote use of the cleaned water and pricing to discourage waste of drinking water.
3. Provisions to reinvest infrastructure and regulatory savings resulting from this program back into the program.
4. Targeted investments in stream restoration, parks, and economic development along stream corridors.
5. Green collar job training to ensure a local supply of experts to tend this new green infrastructure.
6. Incubator space and seed capital for businesses related to, supporting, or supplied by the new infrastructure.

# resilience & decentralization

Sustainability is not only about efficiency and wise use of resources—that is, throughput through a given system—; it is also about the structure of that system. In his seminal book *Soft Energy Paths*, physicist Amory Lovins argues that systems are most efficient when matched in scale and distribution to end-use needs. Lovins was primarily concerned with the energy system, but the principles he outlines are universal. But perhaps more intriguing than the technical argument that Lovins advances is the socio-political argument: that matching scale and distribution to end uses—which, in our present-day hyper-centralized society, tends to mean some degree of decentralization—is also more equitable, egalitarian, and resilient.

The latter point is of particular importance. Whereas centralized systems are more vulnerable to fluctuations, less able to adapt to changing conditions, and often imply large capital investment in both the system itself and its supporting infrastructure, decentralized or distributed systems tend to be more flexible, able to adapt to local conditions, and can take advantage of mass production and modularity to be cheap and accessible. Because of these attributes, they often not only operate more efficiently, but also reduce embodied energy. Indeed, resilience is emerging as an importance theme in the sustainability debate.



Paul Baran made a similar link between resilience and decentralization in the 1960s. Baran, working for the Rand Corp. and the U.S. Air Force, researched communication networks that could withstand a catastrophic “enemy attack.” He created a taxonomy to describe different types of systems—distributed, decentralized, and centralized—and advocated for distributed systems because of their resilience.

The social aspects of decentralization are also worth noting. Lovins argues that large, centralized systems are, by necessity, controlled by expert specialists and organizations that can leverage the requisite capital; as such, they are divorced from democratic decision-making processes. Centralized systems also tend to centralize costs and benefits, which often accrue to different parties at opposite ends of the system: costs accrue “downstream;”

benefits go to those who control the systems that are “too big to fail.” Thus these systems become engines of inequality.

These observations are consistent with those made by anthropologist Vernon Scarborough, who theorizes about two types of social trajectories: one characterized by increasing hierarchy, large-scale capital investments, environmental change, and ultimately collapse; the other characterized by local decision-making, incremental change, and long-term sustainability.

When speaking in generalities, it is best to be wary. Decentralization is not a panacea and should not be approached ideologically. As Lovins notes, the principle task is to correctly match solutions with end use needs. But we must look carefully at the structure of the systems we are designing if we hope to create a sustainable society.