# INSIGHT OUT

Expert Voices on China's Energy and Environmental Challenges

# Waste Power:

## Can Wastewater Revolutionize Pollution Control and Clean Energy in Cities?

Wilson Center

4 January 2018

# China Environment Forum's Role as Convener and Catalyst for Action

For 20 years the Wilson Center's China Environment Forum has carried out research and exchange projects on a broad range of energy and environmental issues in China—from U.S.-China clean energy cooperation and water-energy choke points in China to food safety and the ecological impact of China's overseas investment.

**INSIGHTOUT** is a China Environment Forum publication series that began in 2014. This fourth bilingual issue was made possible with funding from the Henry Luce Foundation, ClimateWorks, and Energy Foundation China, as well as support from the U.S. Environmental Protection Agency through the Global Methane Initiative.

# About the China Environment Forum

For 18 years, the Woodrow Wilson Center's China Environment Forum (CEF) has created projects, workshops, and exchanges that bring together U.S., Chinese, and other Asian environmental policy experts to explore the most imperative environmental and sustainable development issues in China and to examine opportunities for business, governmental, and nongovernmental communities to collaboratively address these issues.

The networks built and knowledge gathered through meetings, publications, and research activities have established CEF as one of the most reliable sources for China environment information and given CEF the capacity to undertake long-term and specialized projects on topics such as energy development in China, environmental justice, Japan-China-U.S. clean water networks, municipal financing for environmental infrastructure, river basin governance, environmental health, water conflict resolution mechanisms, food safety, and environmental activism and green journalism. Our current initiatives are:

- **Global Choke Point:** a multimedia and convening initiative created in partnership with Circle of Blue examining the water-energy-food confrontations in China, India, the United States and other countries around the world.
- **Cooperative Competitors**—research and exchanges on U.S.-China climate and clean energy cooperation.
- **Storytelling is Serious Business**—workshops to help Chinese environmental professionals develop stronger communication skills.
- **Complex Connections**—meetings and research examining environmental impact of Chinese investment overseas.

The China Environment Forum meetings, publications, and research exchanges as well as Global Choke Point activities in India over the past two years have been supported by generous grants from Henry Luce Foundation, Energy Foundation China, Ford Foundation, ClimateWorks Foundation, the U.S. Embassy in India and the Walt Disney Company.

Dr. Jennifer L. Turner has directed the China Environment Forum since 1999. The China Environment Forum is a project under the Wilson Center's Global Sustainability and Resilience Program.

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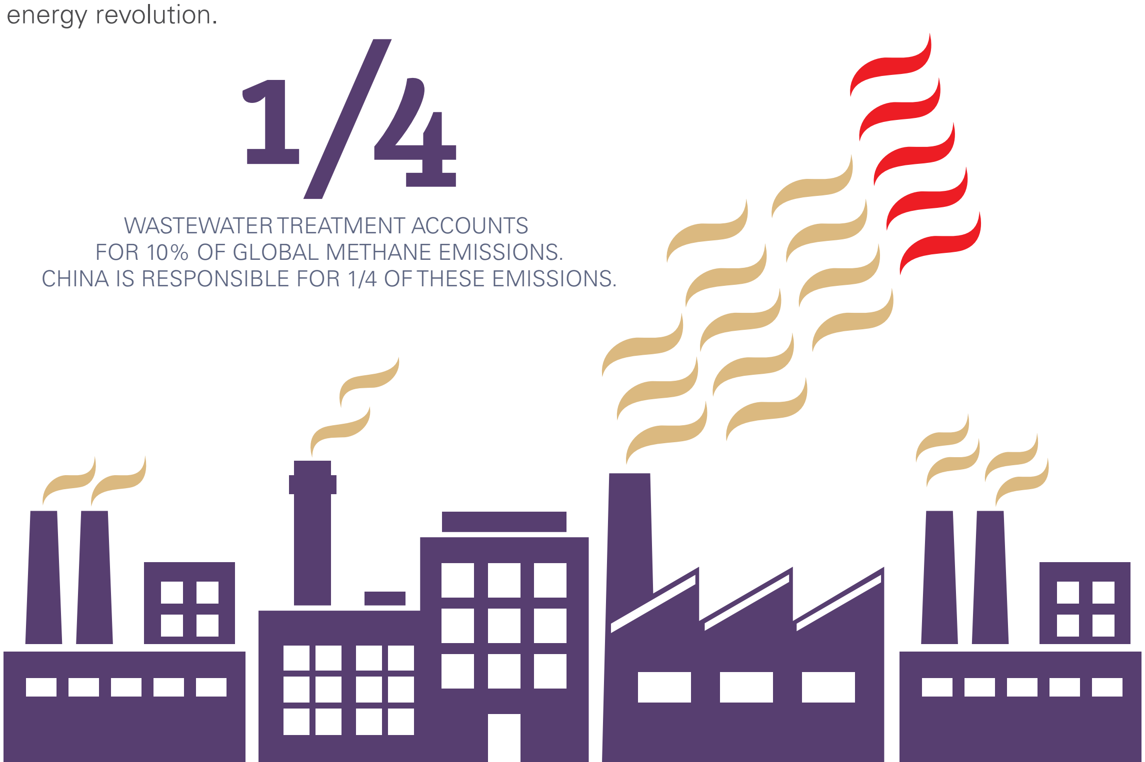
# Waste Power:

## Can Wastewater-to-Energy Revolutionize Pollution Control and Clean Energy in Chinese Cities?

**By Jillian Du**

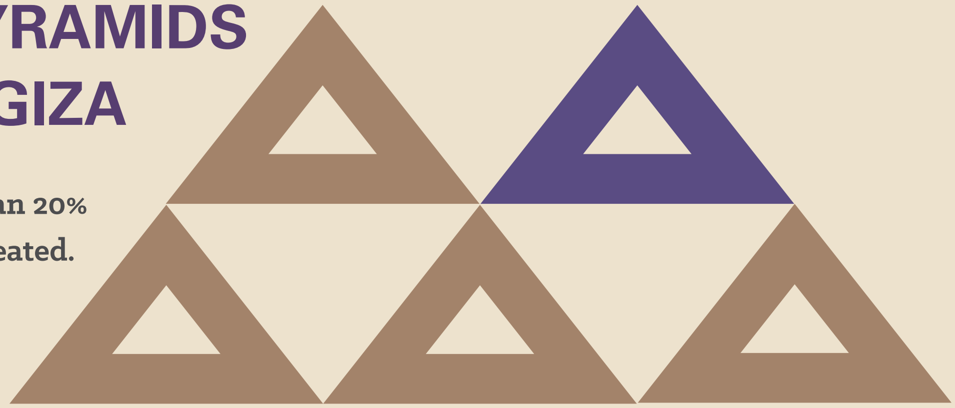
From the flush of our toilets to the food scraps from our kitchens, the future of sewage lies at a crossroads: creating additional sources of energy or more costly sanitation hazards. At the frontlines of a global movement for clean energy, cities are turning to their dirtiest depths to create power from wastewater and sludge. In the United States, several major cities lead the way with innovative strategies that optimize economic benefits, clean energy generation, and pollution control from wastewater treatment. In China, the wastewater-to-power movement is just beginning to catch on; with some of the largest and most densely populated cities in the world, the country could be poised for a sludge-to-energy revolution.

Over the past decades of rapid urbanization, untreated sludge with the toxic byproduct of the municipal sewage treatment process has been quietly contaminating China's soil, groundwater, and croplands. Strikingly, the magnitude of the country's sludge problem and pollution risks did not raise public awareness until late 2013, when Caixin journalists followed trucks from a central Beijing wastewater treatment plant to the city's outskirts, where the drivers illegally dumped untreated sludge into farmers' fields. Concerned citizens tracked down and mapped out the 30+ sludge mountains that were encircling the capital.



China produces over **40 million tons of sludge** enough to fill

# 5 GREAT PYRAMIDS OF GIZA



**with less than 20% properly treated.**

China's wastewater plants produce more than 40 million tons of sludge annually with enough to fill five great pyramids of Giza. Less than 20 percent of this growing mountain of sludge is treated. Chinese cities have largely relied on exporting sludge to landfills and incinerators or illegally dumping untreated sludge into waterways or onto farmland.

As well, China's wastewater treatment plants and landfills are major contributors to air pollution. China is the world's top emitter of greenhouse gases; its wastewater plants alone are responsible for a quarter of global wastewater emissions of methane, a potent greenhouse gas (with emissions alarmingly underreported in China) that traps heat 28 times more powerfully than carbon dioxide.

With hardly any space left at landfills, China's waste incineration plants have more than doubled in number since 2010, releasing a slurry of air toxins that are linked to higher rates of cancer.

Though a dangerous short-term greenhouse gas when released into the atmosphere, methane can also be captured, burned, and used as a valuable energy source. Indeed, methane capture and utilization lies at the heart of the waste-to-energy revolution. Methane capture from wastewater and sludge treatment plants could play a vital role in bringing China back from the brink in terms of sludge management. The success of China's waste-to-energy transition will hinge on major policy directives, market incentives, partnerships, and successful operating models for methane capture.

Encouragingly, China's *2015 Water Pollution Action Plan* tackles the country's long-overlooked wastewater/sludge problem for the first time by setting ambitious targets for cities to improve their underdeveloped sludge treatment capacity. The plan mandates that most prefecture-level cities must achieve 90 percent toxic-free sludge treatment by 2020. Although methane capture and utilization technologies have existed for decades, Chinese city managers and energy and water utility operators have only just begun to explore how sludge-to-energy plants can revolutionize waste treatment systems by generating electricity and mitigating water and soil pollution.

In the United States, cities such as Boston, Oakland, Washington, and Portland have tapped into the waste-to-energy revolution by extracting methane as a biogas from nutrient-rich sludge. These cities are closing the loop in waste and sanitation treatment and producing significant multifaceted benefits and clean energy solutions.

From their position at the forefront of the waste power industry, U.S. utilities and municipalities present partnership and learning opportunities for China. Policy, governance, and financing obstacles have kept most of the 50+ sludge-to-energy pilots in Chinese cities from succeeding. In contrast, U.S. cities have used innovative economic models and technology to best use the energy hidden in wastewater—extracting outputs such as renewable biogas for onsite heating and clean vehicle fuel, as well as digestate used for soil amendments, fertilizers, and cement additives. Plants that capture methane can use it to power and expand their treatment operations, saving the utility money while cleaning water and reducing toxic air pollution and greenhouse gas emissions.

To explore the potential of waste power in Chinese cities, the Wilson Center's China Environment Forum invited six experts from the United States and China to introduce the lessons learned from their experiences with wastewater-to-energy models and to offer recommendations to encourage innovative sludge treatment solutions in China. These solutions place a special focus on major cities, not only because they are at the frontline of today's climate challenge, but also—as the featured pieces show—because they have the greatest potential for energy and pollution mitigation.

From China, **Xiaotian Fu** and **Lijin Zhong** from the World Resources Institute discuss the promising rise of sludge-to-energy by detailing one of the few success stories in China in Xiangyang city, as well as the planned developments in Beijing, Chongqing and Jingmen, and what needs to happen next to

scale up the movement. **Bill Edmonds** from NW Natural Gas in the United States expands on the potential of wastewater as a resource in closing the loop for the transportation sector. **Hongtao Pang** from China Water Environment Group Investment Limited explores the new space for private innovation and the potential for public-private partnerships in China's burgeoning waste solutions market. **David Duest** from the Massachusetts Water Resources Authority's Deer Island Wastewater Treatment Plant and **Christine deBarbadillo** from D.C. Water's Blue Plains Advanced Wastewater Treatment Plant highlight the necessary technology, processes, and motivations that have led to sludge-to-energy success in their cities. Lastly, **Yitong Li**, an environmental technology market expert from Wenzhou Newford Research Institute of Advanced Technology, candidly discusses the key challenges for China's municipal wastewater and the potential for resource recovery from industrial sludge.

This is the fourth issue of CEF's *InsightOut* series, a publication designed to tap on-the-ground expertise to understand the complex energy and environmental challenges faced by China. As with much of our work, we cast an eye on opportunities for the collaboration between American and Chinese researchers, businesses, NGOs, and governments.

1 China Water Risk, "New 'Water Ten Plan' to Safeguard China's Waters," April 16, 2015. http://chinawaterrisk.org/notices/new-water-ten-plan-to-safeguard-chinas-waters/

# Waste-to-Energy: A Solution for Low-Carbon and Green Development in Chinese Cities

**By Xiaotian Fu and Lijin Zhong**

Only four years ago, Caixin journalists uncovered how wastewater treatment plants in Beijing were illegally dumping sludge on the outskirts of the capital. Some Beijing residents discovered a ring of 30+ sludge "mountains" encircling the city. This discovery soon made national headlines and sparked Chinese policymakers to find a solution to this huge gap in municipal waste systems.[1] Very quickly over the past couple of years, China has joined the United States, Brazil, Argentina, and Norway in the movement for resource recovery. With over 100 cities slated for waste-to-energy pilots in the coming decade, China will unleash the potential for this low-carbon, resourceful solution that aids the sustainable development of China's urbanization.

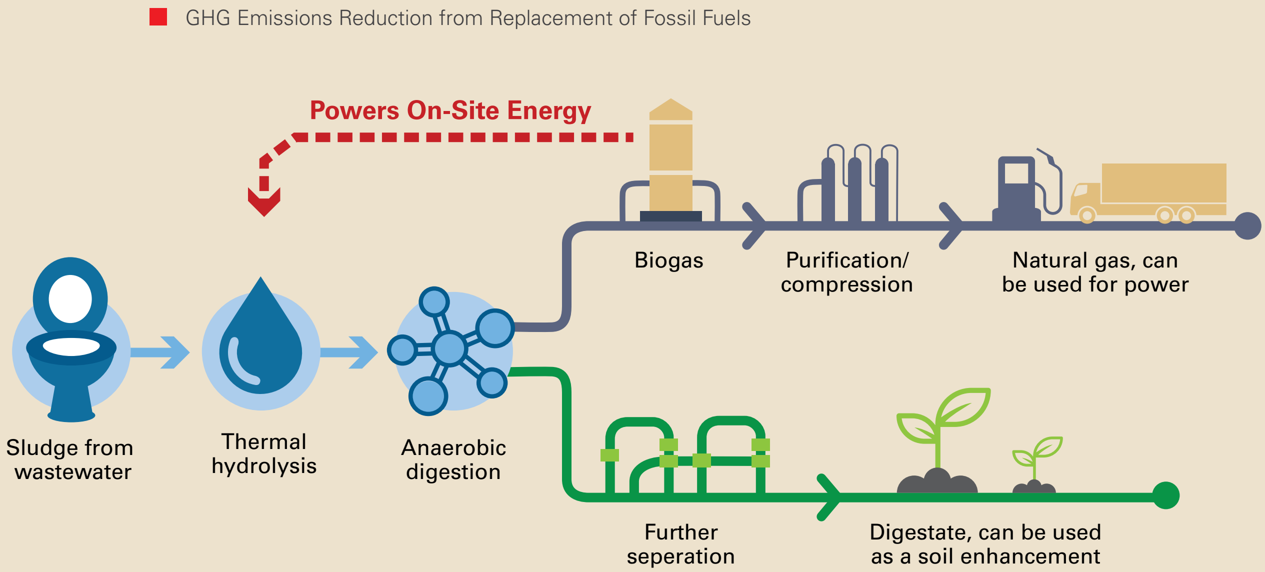
After two decades of rapid urbanization, China is projected to add yet another 240 million people to its cities over the next 20 years.[2] This newest, perhaps final, big surge of urbanites will inevitably be accompanied by a massive increase in the generation of wastewater, sludge, and solid waste.[3] Currently, Chinese cities produce about 40 million tons of sludge from wastewater treatment plants per year.[4] That number will rise. China's urban waste mountains will rise as well, with an additional 60 million tons of restaurant food waste[5] and 190 million tons of municipal solid waste (50–60 percent of which is digestible organic content)[6] being produced annually. These three waste streams pose serious pollution and economic challenges to cities, but also offer an opportunity for innovative waste-to-energy solutions.

Urban waste contains large amounts of organic matter, the disposal of which makes China the world's top emitter of methane—a potent greenhouse gas and short-lived climate forcer. In 2015, the U.S. Environmental Protection Agency estimated that methane emissions from China's wastewater sector make up one quarter of the global emissions from wastewater treatment plants.[7]

## XIANGYANG CITY LEADS THE WAY

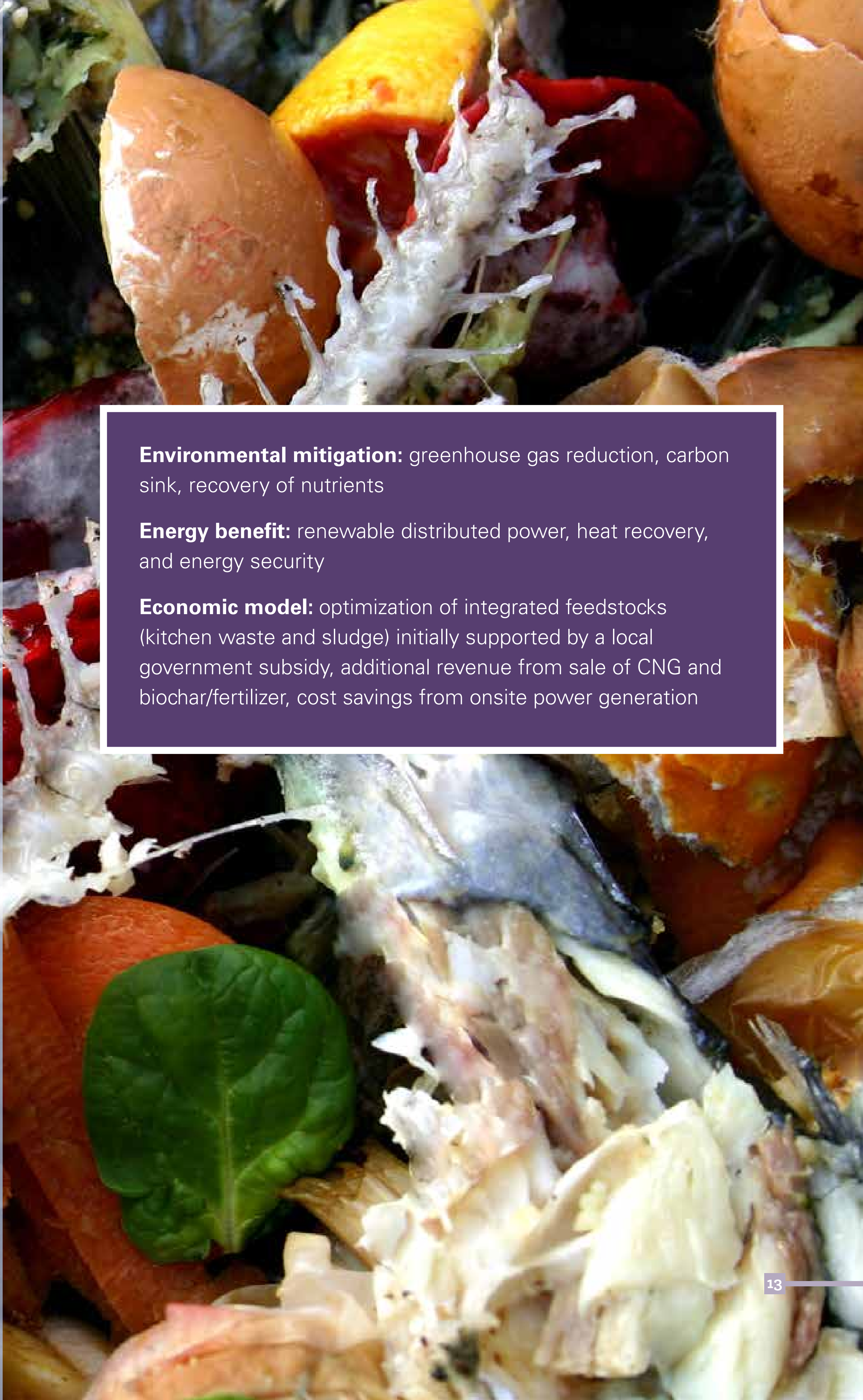
Xiangyang City in Hubei Province became one of the first cities in China to successfully implement the waste-to-energy approach. The municipal government worked with a private Chinese company to use an innovative model to create economic value from the city's waste streams. This approach calls not only for innovative technology and a strategic business model, but also for cooperation among different government agencies and other key stakeholders: the private sector, financing agencies, and nongovernmental organizations.

### Wastewater-to-Energy System




### Treatment Process and Environmentally Beneficial Outputs of the Xiangyang Project

In 2011, Xiangyang invested in a system that combines high-temperature thermal hydrolysis (THP), highly concentrated anaerobic digestion (AD), and methane capture and utilization to co-digest wastewater sludge and kitchen waste. This treatment process uses the high organic content of the sludge and kitchen waste, converting them into natural gas and soil amendment for energy and commercial use. Instead of crowding landfills, it significantly reduces potential pollutants while creating a profitable value chain. The Xiangyang design also successfully integrates the interests of the city government and investors, while producing significant economic benefits for the local community.



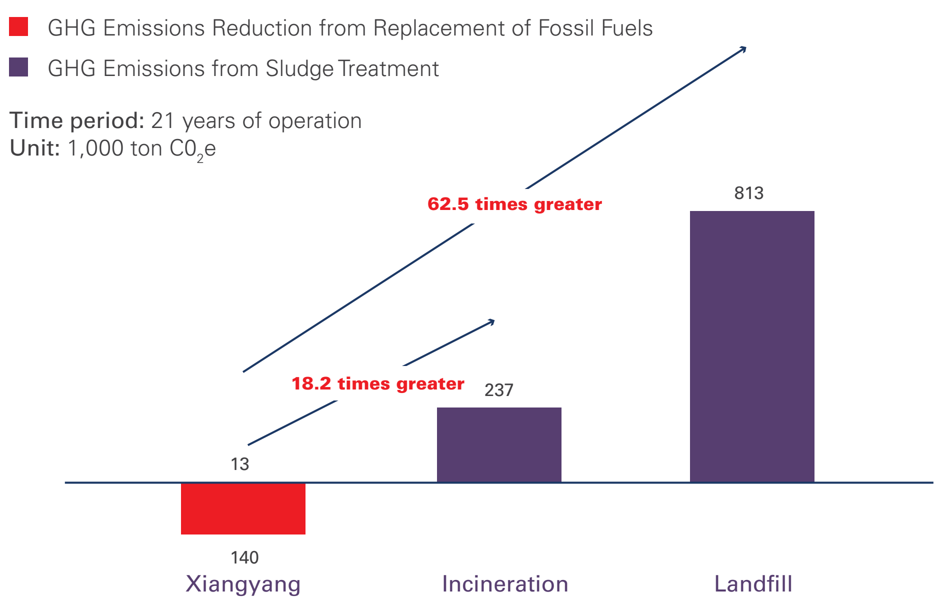
**Environmental mitigation:** greenhouse gas reduction, carbon sink, recovery of nutrients

**Energy benefit:** renewable distributed power, heat recovery, and energy security

**Economic model:** optimization of integrated feedstocks (kitchen waste and sludge) initially supported by a local government subsidy, additional revenue from sale of CNG and biochar/fertilizer, cost savings from onsite power generation

## GHG REDUCTIONS FROM XIANGYANG SLUDGE-TO-ENERGY PROJECT

*Contribution of the Xiangyang Project to GHG Emissions Reduction* [4]




Treating 300 tons of sludge and kitchen waste mixture (about 70 percent sludge and 30 percent kitchen waste) per day, the wastewater treatment plant uses half of the biogas produced for its own operation. The other half (methane) is purified into 6,000 cubic meters of natural gas, which can fuel 300 taxis per day. The project uses leftover treated material to produce a daily output of 60 tons of biochar (a carbon-rich solid with 40 percent water content) to be used as soil amendment to plant trees. The project also plants trees at local landfills to restore the environment. Currently, the sale of both compressed natural gas (CNG) and biochar produces sustainable revenue for the Xiangyang project and reduces its dependency on government subsidies.

The sale of biogas and biochar has the significant added benefit of reducing GHG emissions. Conventional wastewater operations normally rely on large amounts of coal-fired power; this project achieves near-zero carbon emissions. Currently, the Xiangyang project co-digests 108,000 tons of sludge-kitchen waste mixture annually. Based on WRI analysis, the project will emit 98 percent less CO2 than landfills and 95 percent less than incineration.[7] Additionally, the use of CNG to substitute petroleum-based fuels further decreases CO2 emissions, while planting saplings with biochar creates valuable carbon sinks. In total, there is an annual reduction of 36,000 metric tons of CO2—the equivalent of taking 7,700 passenger cars off the road per year.[8]

# EMERGING LOW CARBON SUCCESSES IN BEIJING, CHONGQING, & JINMEN

The case study of Xiangyang shows how a mid-sized city in China can treat sludge and generate clean energy while recovering resources through a cost-effective, circular treatment process. Other Chinese cities are quickly following suit.

**Beijing** is building five sludge-to-energy projects with a total capacity of over 6,000 tons per day. The Xiaohongmen site, near the fourth ring road in southeast Beijing, began trial operations in July 2016. This project uses the same THP+AD technology as Xiangyang to treat 900 tons of sludge (at 80 percent moisture content) per day. When fully operational, the project will be able to produce 40,000–60,000 cubic meters of biogas.

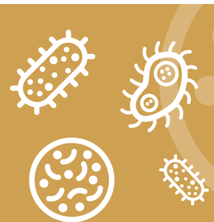
**Jingmen** is planning a circular economy industrial park to treat the city's waste in an integrated way. According to the project design, organic liquid from municipal solid waste will be separated from the dry solids and co-digested with kitchen waste and sludge. Using THP+AD, energy and biochar will be produced from these waste streams. The dry part of the municipal solid waste will have higher caloric value than the original waste volume and will be incinerated as a refuse-derived fuel.

**Chongqing** started co-digesting kitchen waste and sludge in 2010. Every day 1,000 tons of kitchen waste and sludge are co-digested to generate about 20 tons of biodiesel and 50,000 kilowatts of power. The city will further increase the project's capacity to recover more resources, including CNG and biochar.

## SLUDGING FORWARD

Only a handful of sludge plants in China are successfully capturing methane to power their operations and generate marketable products. However, they offer an encouraging model for hundreds of other sludge plants in China to follow. They can teach some important lessons about applicability and scalability for the waste-to-energy movement in Chinese cities:

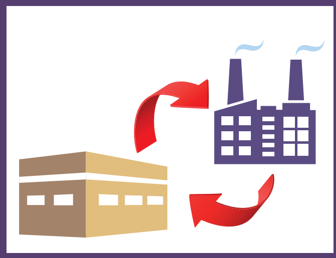
**A market-oriented approach for sludge treatment is vital to its economic success.** As well as saving costs, optimizing market potential for recovered resources will extend financial viability. Xiangyang demonstrated the considerable market potential for CNG and biochar to help ensure a sustainable capital flow.



**Combining and integrating organic waste streams in feedstocks (food waste and sludge) optimizes resource recovery**. Kitchen waste increases the content of organic matter in feedstock, boosting the production of biogas. Meanwhile, sludge harmoniously provides the bacteria needed for the digestion of kitchen waste.

**Ensuring financing mechanisms through public-private partnerships** provides concessional financing to bridge the initial capital investment gap.

**The coordination of government agencies in different sectors is crucial.**



In Xiangyang, kitchen waste is managed by the Urban Management Bureau while sludge is managed by the Wastewater Management Authority. The two agencies must coordinate for the project to succeed. Ultimately, cooperation between China's national, provincial, and local government agencies that manage climate and waste issues will be essential for developing and scaling waste-to-energy systems.

## ENDNOTES


1 Zheng, C., and Z. Liu, "China's Urban Sludge Dilemma: Sinking in Stink," Caixin, August 8, 2013. http://china.caixin.com/2013-07-23/100559622.html.

2 "China's population to reach 1.42 billion by 2020," Global Times—Xinhua, February 7, 2017. http://www.globaltimes.cn/content/1031761.shtml.

3 Hsu, S., "China's Urbanization Plans Need to Move Faster in 2017," Forbes, December 28, 2016. https://www.forbes.com/sites/sarahsu/2016/12/28/chinas-urbanization-plans-need-to-move-faster-in-2017/#2d2cb01e74db.

4 Fu, X., L. Zhong, V. Jagannathan, and W. Fang, Sludge to Energy: An Environment-Energy Economic Assessment of Methane Capture from Sludge in Xiangyang City, Hubei Province, 2017. Washington, DC: World Resources Institute. http://www.wri.org/publication/environment-energy-economic-assessmentsludge-energy-approach.

5 "Development and Trend of Kitchen Waste Treatment Market in China," www.chyxx.com, November 13, 2015. http://www.chyxx.com/industry/201511/358677_2.html.

6 National Bureau of Statistics, China, [Statistics on Consumption Wastes Collected and Transported], 2017. http://data.stats.gov.cn/english/easyquery.htm?cn=C01.

7 U.S. Environmental Protection Agency, Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990–2030, 2012. https://www.epa.gov/sites/production/files/2016-08/documents/epa_global_nonco2_projections_dec2012.pdf.

8 U.S. Environmental Protection Agency, "Greenhouse Gas Emissions from a Typical Passenger Vehicle," 2016. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle-0.

# Renewable Natural Gas: Closing the Loop on Municipal Waste and Creating Clean Vehicle Fuel

**By Bill Edmonds**

*A clean energy revolution is taking place in the United States from an unexpected resource: methane captured from sewage, food, and farm waste. Waste methane that would otherwise be burned off or emitted directly to the atmosphere is now being cleaned up to pipeline standards in nearly 50 projects around the country, creating renewable natural gas (RNG).*

Converting organic waste into an energy source creates new revenue opportunities for RNG producers such as wastewater treatment plants (WWTPs). Connecting this renewable energy stream to the transportation sector provides a new pathway for driving down carbon and other emissions from the vehicle sector. According to the Union of Concerned Scientists, in 2013, vehicles contributed more than half of the U.S. carbon monoxide (CO) and nitrogen oxide ($NO_x$) emissions released into our atmosphere, both of which act as potent short-term climate forcers and precursors to smog.[1] According to the U.S. Environmental Protection Agency, in 2015, cars in the United States contributed to 27 percent of national carbon emissions. Diesel-powered heavy-duty vehicles used to move goods and services are major contributors to transportation-related smog in urban areas. They are unlikely targets for electrification, but present an opportunity for natural gas.

**USING 100% RNG** in vehicles can reduce **GHG** emissions by more than **80%**

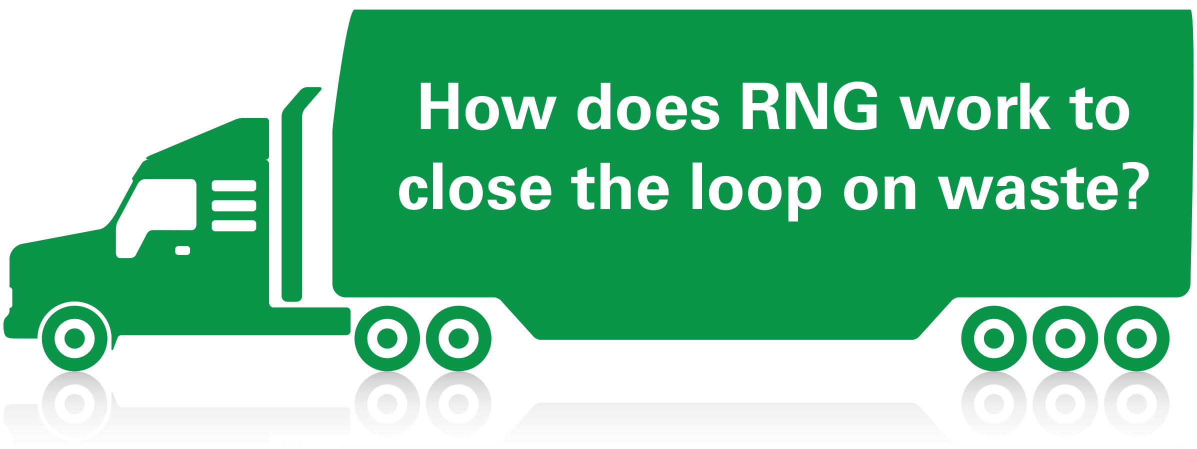
**USING 20% RNG-blend** provides a **GHG** reduction between **26%** and **30%**

**RNG** from some sources are **carbon negative,** meaning that they sequester **GHG** during the fuel lifecycle

*Substituting conventional natural gas for diesel fuel can reduce NOx emissions by 90 percent, a move that would greatly improve air quality in major cities. In addition to smog reduction, switching to renewable natural gas will further reduce the carbon emission from these heavy vehicles, such as refuse haulers and transit fleets using near-zero emissions engines, by as much as 80 percent.*

## FEEDING A MARKET HUNGRY FOR A CLEANER ALTERNATIVE TO DIESEL

Thirteen states have adopted California's vehicle emission standards, which are stricter than those in the federal Clean Air Act.[2] According to an Environmental Defense Fund report published in December 2016, California and the Clean Air Act's clean car standards will enhance energy security in the United States and reduce oil consumption by nearly 2 million barrels per day by 2025.




*Sewage and food waste from a city's population are piped and trucked to the WWTP on the edge of a city. That waste is processed in an anaerobic digester, capturing its useful methane called biogas, which can then be upgraded to a higher BTU level and conditioned into RNG.*

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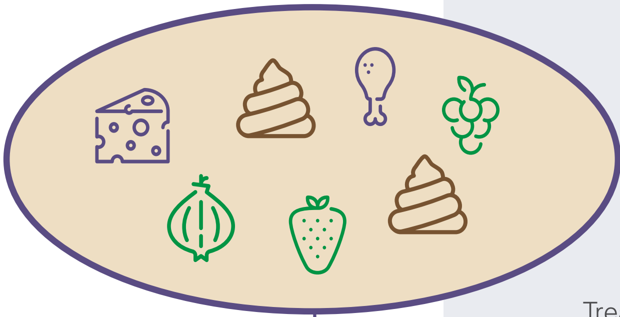
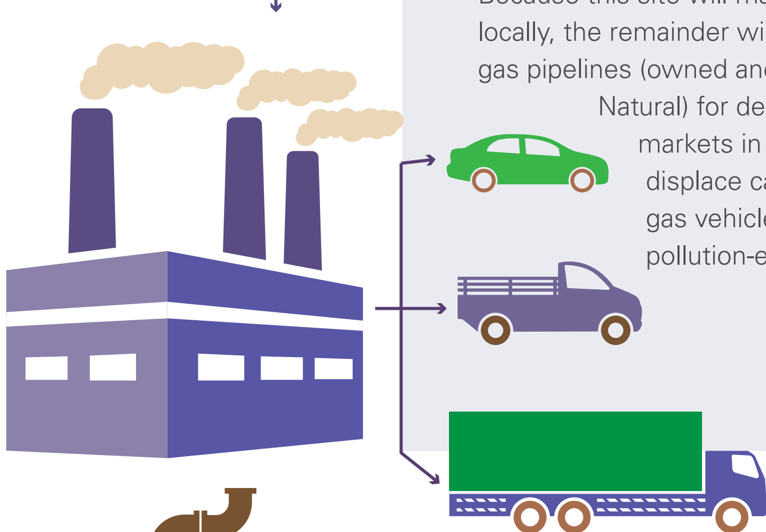
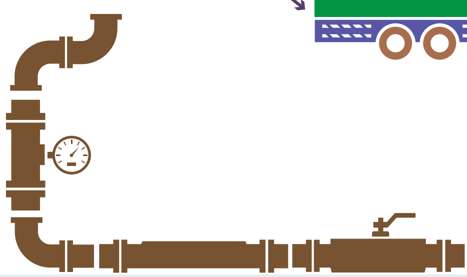
Both conventional natural gas and RNG provide a ready substitute for diesel in heavy duty vehicles. RNG can be used on site to refuel heavy-duty trucks that operate on compressed natural gas (CNG). Producers that connect to the gas grid may distribute RNG to a broad geographic area, in order to reach a wider market for CNG vehicles far from the plant.



## LINKING RNG WITH TRANSPORTATION

In Portland, Oregon, a project is underway to link WWTP-produced RNG with the transportation sector. The Columbia Boulevard Wastewater Treatment Plant, the city's only treatment plant, serves over 600,000 customers. When its biogas conditioning project wraps up in 2018, a portion of the RNG produced will be used to refuel Portland city fleets and the plant's own trucks. Because this site will make more RNG than can be used locally, the remainder will be compressed and injected into gas pipelines (owned and operated by the local gas utility, NW Natural) for delivery to the larger, more mature fuel markets in California. There, RNG will further displace carbon-intensive oil and conventional gas vehicle fuels, thus closing the waste-pollution-energy loop.





In the future, the Columbia Boulevard RNG project could expand to accept municipal food waste, a resource that generates methane gas through anaerobic digestion. In an example of closed-loop resource design, the same trucks used to gather Portland's food waste could be refueled using RNG derived from that food waste.

## WASTE AS FOOD: RESOURCE RECOVERY

Today, the United States has about 50 RNG projects connected to natural gas pipeline systems. As cities across the world begin scaling up their own resource recovery efforts, we can glean some early lessons from these initial efforts to turn wastewater and biosolid treatment plants into energy generators:

» **There is enough RNG to matter.** RNG from both anaerobic digesters and (eventually) gasification of food waste could replace more than 25 percent of the conventional natural gas being used for residential, commercial, and industrial purposes in the United States—a significant amount.


**of Natural Gas used in transportation today is RNG**

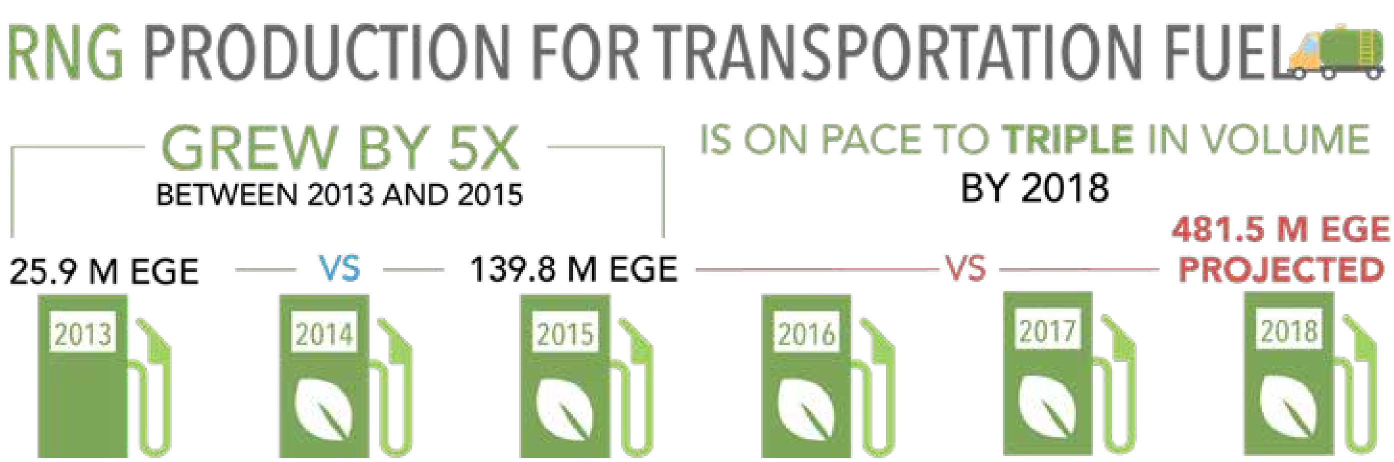
» **Renewable gas production for heating and transportation sectors may trump other forms of electricity generation.** The Columbia Boulevard facility in Portland, along with many other WWTPs, currently uses some biogas on site to fuel boilers for processing and facility heat, and as fuel for combined heat and power (CHP) units to produce both electricity and heat. The facility delivers excess biogas to nearby industrial customers; remaining gas is burned off in a flare. Portland's proposed RNG project will take the flared gas first, but as the local market develops, the city may divert gas from industrial customers as well because of its value to the city's transportation market.

The economics of producing electricity from biogas and fuel for the transportation market will vary in every city depending on several factors: the total gas production at the plant, the age of the CHP unit and costs of maintaining it, the plant's proximity to a suitable gas pipeline, and the local price in the market for both commodities.

» **RNG is interchangeable with natural gas.** Gas utilities that manage local pipeline distribution infrastructure are critical to ensuring the success of wastewater and biogas generated RNG. These gas companies will ensure that the RNG they accept on their pipeline operates interchangeably with conventional gas. Namely, the RNG: (1) has the same thermal content as conventional gas, and (2) does not contain impurities that present risks to the utility system or operational challenges for customers. Projects injecting RNG into the pipeline have been largely successful; as more projects are developed, we should expect innovations in the conditioning process that perform reliably at a lower cost.

» **Incentives create markets.** U.S. policymakers have placed a high priority on encouraging renewable fuel sources for the transportation market. The Federal Renewable Fuel Standard has created a sizeable incentive for flowing RNG into transportation markets. State laws, especially California's Low Carbon Fuel Standard and Oregon's Clean Fuel Standard, add further incentives for RNG in the transportation sector. Together, these incentives have created a sizable demand that has driven RNG from all around the nation into the California market. Today, half of all CNG vehicles in California run on RNG.

» **RNG facilitates local economic development and provides resiliency benefits.** Because RNG is an energy source with local customers, most of the economic benefits of producing it stay within the city, where those benefits are multiplied—a phenomenon that has been studied in detail for local energy efficiency expenditures.[3] Local RNG is also more likely to be available in a time of emergency, providing resiliency to a city's broader energy system.



## CLOSING THE LOOP

In essence, RNG production provides the missing link to closing the urban waste–pollution–energy loop. It allows a city to capture unused methane emissions from biological waste treatment and turn it into valuable renewable fuel that can be delivered efficiently throughout the existing gas distribution systems.

RNG provides a homegrown, locally managed energy source that benefits U.S. communities. Both policy and technical advances that are helping to spur the RNG market in the United States can be deployed in China's quickly urbanizing areas, where current investments in large WWTPs can integrate this technology to provide substantial environmental and community benefits.

RNG production opens up a new frontier for U.S. and Chinese cities, new systems and technologies to extract greater value from the waste stream. As the world's largest energy consumers and waste producers, both countries have an important role to play in designing and deploying new resource recovery models.

## ENDNOTES

1 http://www.ucsusa.org/clean-vehicles/vehicles-air-pollution-and-human-health/cars-trucks-air-pollution#.WIkSRGeQyRs

2 Reductions of this scale are possible using a new "near-zero-emissions" engine. See Gladstein, Neandross & Associates, Game Changer: Next Generation Heavy-Duty Natural Gas Engines Fueled by Renewable Natural Gas, May 2016, section 9.3 https://www.edf.org/news/13-states-adopting-california-clean-car-standards-would-reap-significant-economic-and-environme

3 http://www.ourenergypolicy.org/wp-content/uploads/2012/10/SynapsePaper.2012-08.ACEEE_.Economic-Impacts-of-EE-in-VT.S0073.pdf

*All graphics provided by Renewable Natural Gas Coalition*
*Photo credit: NW Natural*

# No Silver Bullet: Crafting Specific Solutions to China's Varied Sludge Challenges

**By Hongtao Pang**

The sludge challenge in China is not only immense but uniquely complex. China's municipal sludge will nearly double by 2020, yet major cities like Beijing currently treat only 23 percent of the sludge being produced. Over the years of conducting research and planning for several public-private-partnership watershed management projects in China, I have seen many attempts by Chinese industry experts and managers to tackle sludge treatment and disposal and gained insights into the major challenges:

- The sludge in China contains low levels of organic matter and has very high sand and water content. Chinese cities lack the appropriate technology in their current sludge treatment systems to tackle this kind of content.
- Over the past decade, city managers and central policymakers have handled the large and growing sludge production with limited vision and short-term solutions, leading to landfills at overcapacity and high operation costs for incinerators.
- At the provincial and municipal levels, there has been a lack of accountability as well as policy and regulatory support to encourage sustainable sludge treatment.
- City and provincial governments have been investing very little into sludge treatment infrastructure and facilities. Moreover, sludge treatment charges have been set very low and cannot cover operation costs.
- China's sludge industry is still young; no Chinese city has emerged as a true leader in demonstrating a technology that meets high treatment standards. To close the loop of waste-to-resource, sludge treatment needs to reach a higher standard to produce more reliable and economical products (e.g., sanitized agricultural compost).

- The lack of markets is another big area of concern in my experience—China does not allow the use of treated sludge on farms and there are few markets or incentives for soil amendments/compost, or even for biogas. The Chinese government could establish favorable procurement policies and certification criteria to encourage the use of these materials. Such certifications could be adapted from the U.S. Composting Council or the American Biogas Council.

# The Funding Gap

## 4.6 Billion (USD)

*The neccessary investment to advance China's sludge treatment and disposal to meet the the 13th Five-Year Plan Goals*

China's sludge industry is developing rapidly, and many industry insiders are optimistic that the government will create more financial and policy incentives for sludge treatment during the 13th Five-Year Plan period (2016–2020) and that the resulting market will be enormous. But future development of China's sludge treatment depends on boosting market forces and encouraging favorable policies. Fortunately, a few national policies and regulations are starting to prompt cities in the right direction.

- **The Water Pollution Action Plan for Prevention and Treatment (2015)** states that existing sludge treatment and disposal facilities should be upgraded to meet national standards by 2017, and city sludge treatment rates in prefecture-level cities should reach 90 percent by the end of 2020.
- **The Soil Pollution Prevention Action Plan (2016)** proposes the use of treated sludge for urban landscaping and forestry planning.

- The 13th Five-Year Plan **National Urban Sewage Treatment and Recycling Facilities Construction Planning (Draft) (2016)** requires that sludge treatment rates reach 90 percent in municipalities, 70 percent in counties, and 50 percent in towns by 2020.
- The National Development and Reform Commission, the Ministry of Finance, and the Ministry of Housing and Urban-Rural Development jointly issued the **Notice of the Development and Adjustment of Sewage Treatment Fees and Other Issues (2015)**, requiring appropriate charges to compensate sewage and sludge treatment facilities for operating costs.

## CREATIVE THINKING ON TECHNOLOGIES

To move market forces in the right direction, this nascent industry needs a multi-technical approach specific to China's challenges. For example, while sludge-to-energy systems using anaerobic digestion (AD) have become an optimal choice for many major cities across the world—used by 60 percent of the treatment plants in Europe, the United States, and Japan—they may not be the silver bullet for China's sludge. In China, only 60 out of 3,830 urban sewage treatment plants have this technology installed, and only a handful of them use it regularly. For many companies, this AD technology requires a large investment while operations and management are complicated due to the high sand content of China's sludge. The varying levels of organic content have limited the quantity and quality of biogas production from Chinese sludge treatment plants, which means little to no energy can be produced and treating the sludge becomes very expensive.

However, AD is not the only choice. Sludge treatment can also employ low-temperature drying technology to recover heat and treated biosolids. This technology does not rely on the sludge's sand to organic content ratio, and its facilities are easier and cheaper to run with less needed space. Dehydrated sludge is dried to 60 percent

reduced water content, while the temperature of sludge is controlled below 65°C. The sludge volume is reduced significantly while the energy consumption of this process is significantly lower. Afterwards, the dried sludge can be used for composting, incineration, or building material, or as a cement additive.

As operational and initial capital investment costs for this technology drop, we can expect a promising future for dehydrating, de-voluming, and multi-technical approaches for sludge treatment in China.

The Xiangyang sludge-to-energy plant, used with permission courtesy of TOVEN.

## NEW KINDS OF PARTNERSHIPS

To create a self-sustaining industry, there must be more room for public-private partnerships.

For sludge treatment and disposal, promoting public-private partnerships (PPPs) will encourage private sector collaboration for innovative business models. The 13th Five-Year Plan indicates a necessary 31.6 billion RMB (4.6 billion USD) investment into sludge treatment and disposal facilities, pointing to the private sector to help finance the gap. The current operational model of the sludge market relies heavily on government subsidies. For the projected growth of China's sludge mountains, this financing deficit needs to be largely improved.

PPPs can significantly improve investment efficiency. A private company can bid on planning and design, financing, construction, and operation, while the government provides oversight and pays on performance. In partnering with local government, the company I work for—the China Water Environment Group—has successfully practiced and implemented such projects for water and sanitation infrastructure in the cities of Guiyang (Guizhou Province) and Guang'an (Sichuan Province). With our professional expertise and cooperation of local officials, our project built a piped network and improved the local sewage system, sewage treatment center, and watershed management.

Ultimately, to realize China's ambitious goals for sludge treatment, there must be better public and private collaboration and the ability to use varied technical approaches that fit local wastewater and sludge content. Lastly, appropriate project financing for systems that close the loop between waste to resource will be absolutely key.

# Brown Is the new Green at Metropolitan Boston's Sewage Treatment Plant

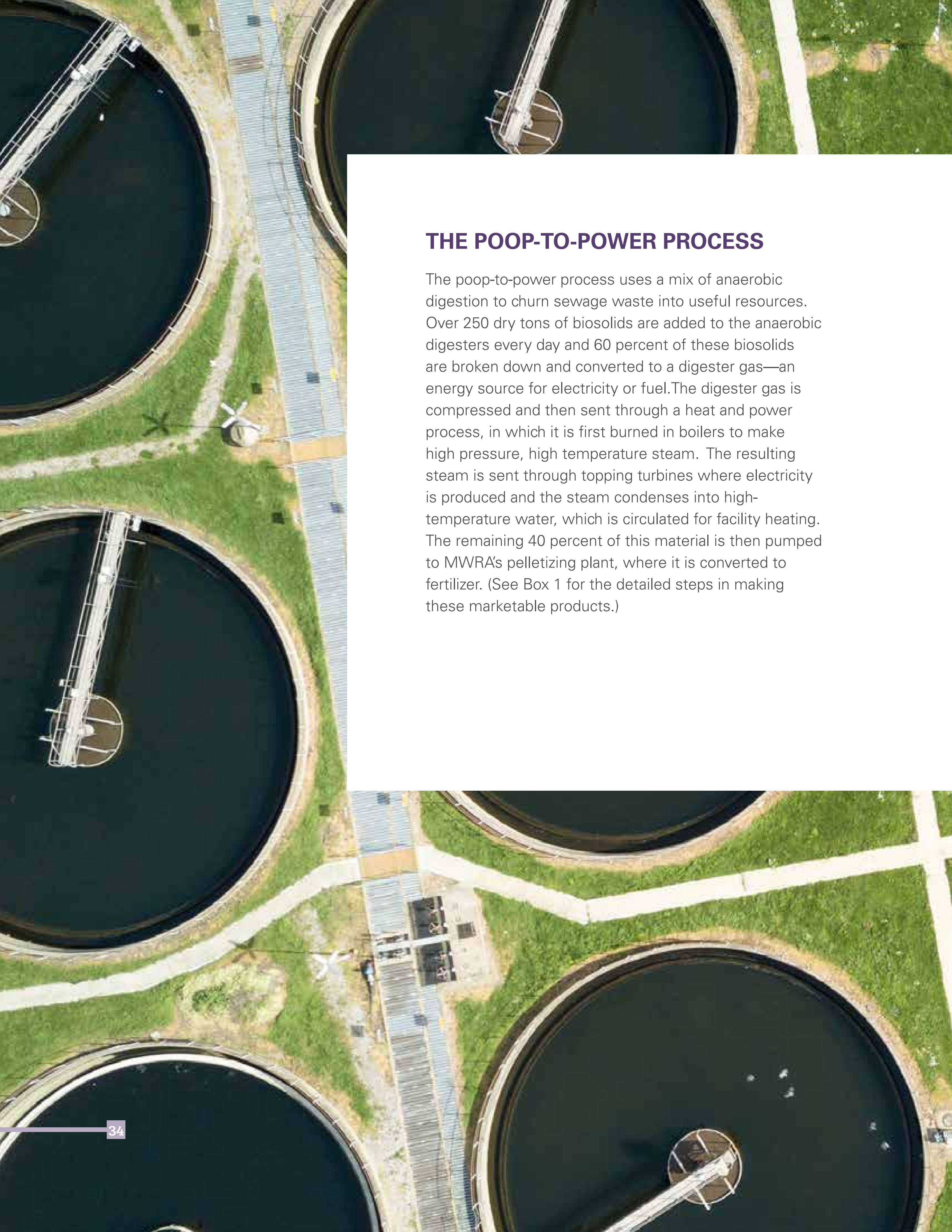
**By David Duest**

Boston residents likely do not realize that beneath their feet flows a major source of clean energy—the city's sewage. Just outside Boston, the Massachusetts Water Resources Authority's (MWRA's) Deer Island Treatment Plant demonstrates a strong commitment to public health and sustainability by turning brown sludge into green energy. From cost savings to resource recovery, Deer Island leads by example in community impact and environmental achievements.

Wastewater treatment plants are a costly operation, using significant amounts of daily heat and electricity in the pursuit of their mission. Plant operators in cities around the world are looking for more sustainable ways to minimize energy use and maximize energy production from the products they extract during the cleanup of wastewater. Within the last ten years, Deer Island has achieved significant cost savings for its ratepayers by using sludge/biosolids—normally a landfilled "brown" product, loaded with bacteria—from wastewater treatment as a means to produce significant quantities of renewable "green" energy.

## ON THE FRONTLINES: THE DEER ISLAND TREATMENT PLANT

Deer Island treats wastewater from 2.3 million people, or 34 percent of Massachusetts' population, from 43 communities in the Boston metropolitan area. The plant has a designed maximum capacity of 1.31 billion gallons (4.95 million cubic meters) per day—making it the second largest treatment plant in the United States—with an average design flow of 361 million gallons (1.363 million cubic meters) per day.



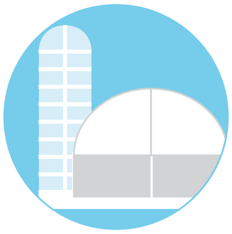
## THE POOP-TO-POWER PROCESS

The poop-to-power process uses a mix of anaerobic digestion to churn sewage waste into useful resources. Over 250 dry tons of biosolids are added to the anaerobic digesters every day and 60 percent of these biosolids are broken down and converted to a digester gas—an energy source for electricity or fuel.The digester gas is compressed and then sent through a heat and power process, in which it is first burned in boilers to make high pressure, high temperature steam.  The resulting steam is sent through topping turbines where electricity is produced and the steam condenses into high-temperature water, which is circulated for facility heating. The remaining 40 percent of this material is then pumped to MWRA's pelletizing plant, where it is converted to fertilizer. (See Box 1 for the detailed steps in making these marketable products.)

## Box 1. Steps from Brown to Green

***Step 1: Detox and release***

Wastewater first travels through grit removal, primary treatment, and then oxygen-activated sludge treatment. The treated water, called effluent, is then disinfected, dechlorinated, and disposed of. More than 94 percent of the solids in Deer Island's incoming wastewater are removed using this treatment process. Deer Island's outfall discharges the treated effluent 9.5 miles offshore, into the deep waters of Massachusetts Bay.



***Step 2: Digesters turn solids into biogas***

Wastewater solids (sludge and scum) removed from primary and secondary treatment are thickened and sent to Deer Island's 12 iconic egg-shaped anaerobic digesters. These digesters, standing nearly 140 feet tall, hold 3 million gallons of sludge (only 5.5 percent of which is solid) for 18 to 22 days. They are the heart and soul of Deer Island's "brown to green" sustainable operation. The digesters anaerobically break down wastewater solids into a sustainable yet weak form of natural gas, a valuable fuel for use in Deer Island's operations.

***Step 3: From sewage to "Class A" fertilizer***

Deer Island pumps any remaining solids 7 miles across the harbor to an offsite pelletizing plant for further processing into a high-quality "Class A" fertilizer (the top rating according to U.S. Environmental Protection Agency standards). Deer Island sells the fertilizer to residents throughout the eastern half of United States as "Bay State Fertilizer," an effective soil enhancer.

## BROWN IS THE NEW GREEN: MOTIVATIONS FOR CONTINUOUS IMPROVEMENT

**Economic model for success.** The conversion of wastewater ("brown") solids to a renewable fuel (a "green" product) is a huge boon for the treatment plant and a major cost-saving measure for the MWRA. One of these beneficial "green" products is digester gas. **The produced digester gas meets more than 95 percent of the plant's heating needs and 23 percent of the plant's electricity needs, equivalent to $18–22 million dollars per year.** Deer Island has an annual budget of slightly more than $60 million, saving nearly a third of original costs. Without digester gas, Deer Island's budget would exceed $80 million.

As well as saving money by using digester gas, MWRA has diversified its green portfolio by installing two 1.1 MW hydroelectric generators, two 600 kW wind turbines, and 756 kW worth of solar panels. All in all, onsite green energy meets 30 percent of Deer Island's electricity demands.

**Policy directives shaping renewable energy and integrated waste streams trends.** Another waste-to-energy trend is the diversion of food waste from landfills for co-digestion with wastewater, in order to maximize organics recycling and minimize waste emissions. In collaboration with the Massachusetts Department of Environmental Protection (MaDEP), MWRA began looking toward the co-digestion of food waste as a way to dramatically increase biogas and green energy production while diverting the last recyclable material from going to landfill. Thus, MaDEP opened up the state's regulations to allow the diversion of food waste to publicly owned treatment plants equipped with anaerobic digestion and digester gas recovery. MWRA also performed several studies while trying to implement the region's first publicly owned treatment co-digestion program. Unfortunately, due to Deer Island's remote location, transportation costs outweighed the green benefits.

**Figure 1.** *MWRA's facilities: 98% of the plants heating needs and 22% of the plant's electricity needs are created in-house through the process*

Nonetheless, MWRA has used its co-digestion research to help other public works around the U.S. take advantage of this important opportunity. **Beyond Massachusetts, wastewater treatment plants nationwide are leveraging anaerobic digestion with integrated waste recovery as a major sustainable and cost-saving practice.** In fact, the U.S. Environmental Protection Agency and the U.S. Department of Energy have been touting the benefits of anaerobic digestion as a key component of the water-energy nexus.

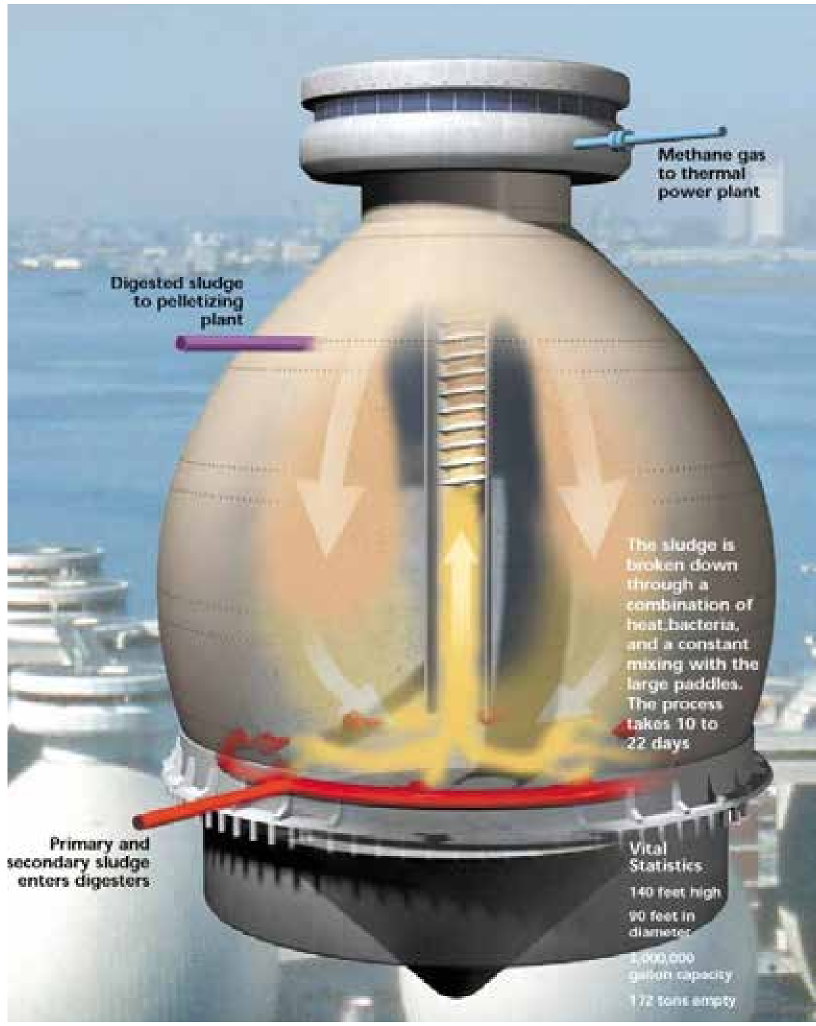



**Figure 2.** *Anaerobic Digestion: MWRA uses 12 of these egg shaped digesters in the process*

**Community interests: health and affordability.** MWRA takes its role as a protector of public health and the environment seriously. It defines itself as an environmental leader and tries to practice what it preaches in all of its daily operations. Since MWRA gets funding directly from the local communities it serves, it has always felt a tight connection to its ratepayers and a need to operate as well as it can at a reasonable cost. Using digester gas as a green energy source is key to meeting these goals, as it helps reduce costs for ratepayers while mitigating climate pollution. Ultimately, MWRA's embrace of the waste-to-energy frontier has allowed it to magnify sustainability and affordability benefits for its local community.

*To learn more visit: http://www.mwra.com/*

**Figure 3.** *Bay State Fertilizer: MWRA produces "Class A" fertilizer that is sold to residents of the eastern U.S.*

# Innovative Biosolids Management at DC Water

**By Christine deBarbadillo**

For the more than 2 million residents of Washington, D.C., and the adjacent counties in Maryland and Virginia, every flush of their toilets helps generate electricity or resources to power the U.S. capital. This is all thanks to DC Water's Blue Plains Advanced Wastewater Treatment Plant, the largest single-source consumer of electricity in the District of Columbia. Over this last decade, Blue Plains has reduced its carbon footprint by 40 percent by offsetting its electricity needs with renewable power and recovering biosolids as a usable resource.

Blue Plains Advanced Wastewater Treatment Plant has a treatment capacity of 1.4 million cubic meters per day, with a peak capacity (partial treatment during large storms) of 4 million cubic meters per day. The site occupies 60 hectares in the southwest quadrant of Washington, D.C., and the plant discharges to the Potomac River. Since the mid-1980s, Blue Plains has been upgraded to reduce both total phosphorus and total nitrogen to improve water quality in the Potomac River, and for the restoration of the Chesapeake Bay.

**Figure 1.** *Aerial Photograph of Blue Plains Advanced Wastewater Treatment Plant in Washington, D.C.*

## INNOVATIVE AND SUSTAINABLE BIOSOLIDS MANAGEMENT

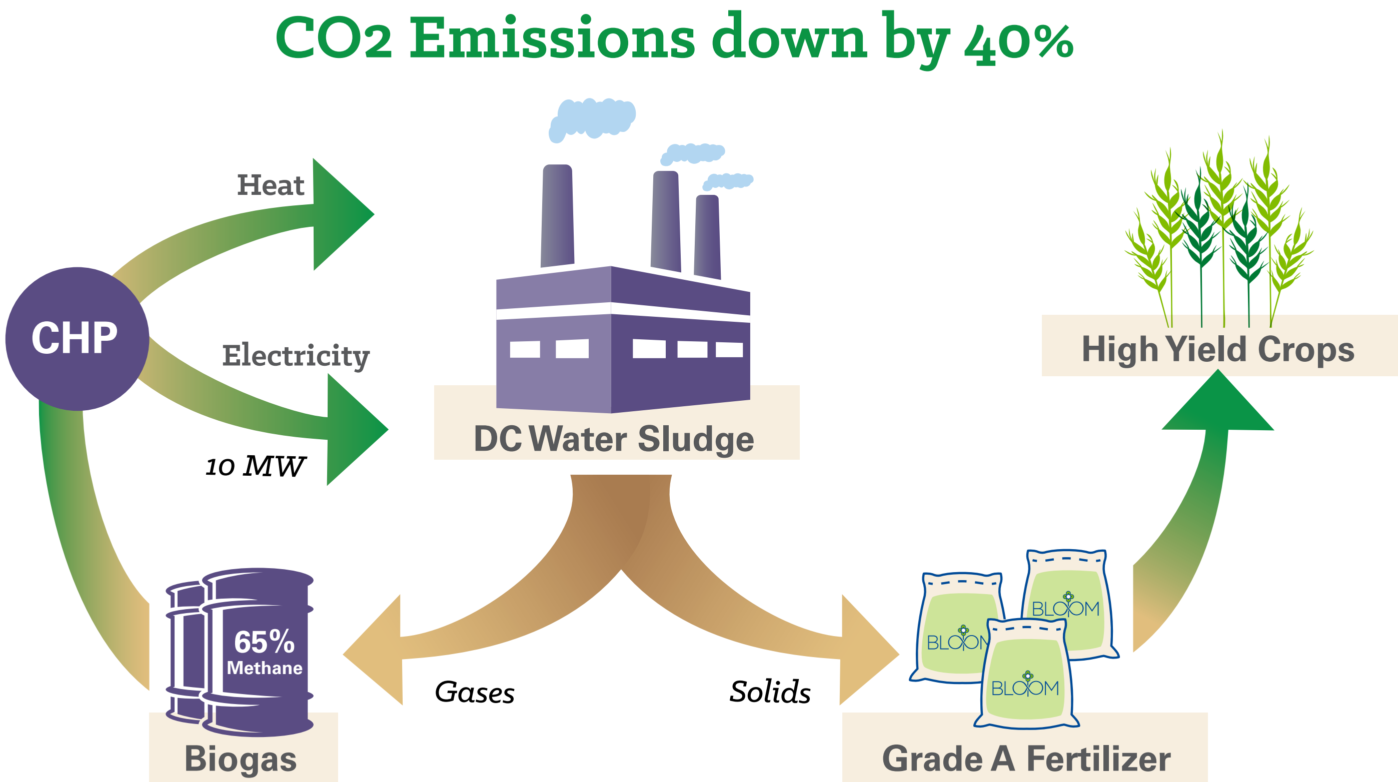
For many years, raw and biological sludge solids were thickened to a slurry, then further dewatered to a cake-like consistency and classified as a Class B biosolid. This worked, but DC Water needed a solids handling solution that would reduce quantities and be environmentally and economically sustainable for the long term. Therefore, in 2009, DC Water launched a program to convert the Class B lime stabilization sludge processing facility at Blue Plains into an innovative, sustainable Class A biosolids system. A decade of research and development efforts led DC Water to become the first utility in North America to use thermal hydrolysis for solids treatment—and the largest thermal hydrolysis plant operating in the world.

Thermal hydrolysis (pressure cooking of the solids) is the key step in the new solids treatment facilities that were commissioned in September 2014 and began processing the entire solids load in February 2015. After solids screens and pre-dewatering centrifuges, the biosolids go through the  thermal hydrolysis process, followed by anaerobic digesters and belt filter presses.

The true innovation of the process is its use of thermal hydrolysis followed by anaerobic digestion (using microorganisms to break down solids) to convert wastewater solids into a stable, low-odor, Exceptional Quality Class A biosolids product. This opens new ways for DC Water to create beneficial use and product revenue. (see Figure 3.) In addition, thermal hydrolysis significantly changes the sludge biodegradability, making it easier to pump and mix. The resulting thicker solids stream from this pretreatment process reduces volume required for anaerobic digestion by half, saving millions of dollars in construction costs.

**Figure 2.** *Thermal Hydrolysis and Digestion Facilities at Blue Plains Advanced Wastewater Treatment Plant*

## DC WATER CLOSING THE WATER-ENERGY LOOP




## REDUCING CONSUMPTION AND EMISSIONS

This innovative wastewater treatment also helps minimize energy and heat demands by generating onsite renewable power.

Biogas produced through anaerobic digestion is about 65 percent methane, meaning it can become a valuable renewable fuel. In 2015, Blue Plains added a combined heat and power (CHP) facility to use this biogas. In the facility, turbine exhaust is directed to heat recovery steam generators to produce the steam needed to heat and pressurize the thermal hydrolysis reactors. The CHP facility provides about 10 MW of renewable power to Blue Plains, reducing energy consumption of fossil fuels by about one-third.

> Offsetting the plant's electricity needs with renewable power and reducing the biosolids hauling and emissions has reduced the Blue Plains carbon footprint by 40 percent.


**Figure 3.** *The benefits of Class A biosolids*

*The new Exceptional Quality Class A biosolids product has many more reuse options as a soil amendment than the former Class B product. It has a smaller volume, and when land-applied will reduce hauling and emissions, further reducing the plant's carbon footprint. DC Water is currently developing and marketing the high-quality soil amendment as Bloom®.*

## COST-SAVING MOTIVATIONS

Innovative biosolids management has yielded considerable savings and new opportunities for DC Water, which expects to save about $2 million annually on treatment chemicals and $11 million annually in trucking expenses.

In May 2016, DC Waste launched its Class A biosolid as a revenue-generating compost product called Bloom. Bloom is now available in the District of Columbia and Maryland, in bulk and in both fresh and cured forms, for soil blenders, nurseries, landscapers, community groups, and governments. Bloom shows the market potential of recovered resources in our everyday waste streams, as innovative waste recovery technologies can help cities achieve major economic and environmental benefits.

**Blue Plains is currently the world's largest thermal hydrolysis installation.** The second-largest installation, from the same Norwegian designer, began operating in Beijing in 2017. Blue Plains illustrates how a decade of prioritizing and investing in facility advancements can have significant environmental and economic benefits for the U.S. capital. Should China's capital remain committed to similar long-term investments—as it appears to be, given the five similar plants slated to open by early 2018—we may expect even more impressive results.

To learn more about DC Water and Bloom, see https://www.dcwater.com/ or http://bloomsoil.com/.

**Bloom provides greater crop yields and better drought resistance. It is also great for the home garden and lawn care.**

# Moving Beyond a One-Size-Fits-All Solution for China's Municipal and Industrial Sludge

**By Yitong Li**

After spending 20 years in China's environmental technologies business, I am optimistic that treatment for China's sludge mountains is finally headed in the right direction. In parallel with the launch of *The Action Plan for Prevention and Treatment of Water Pollution* in 2015, market opportunities for municipal and industrial wastewater and sludge treatment in China have grown dramatically.

Great market potential exists for both upgrading conventional water treatment plants and increasing overall treatment capacity. Based on experiences with my customers in the past two years, the market demand for wastewater treatment technologies is growing fast. Meanwhile, government policies and regulations encourage market growth for treatment. The key to the next phase is finding the right approach to satisfy market demands and clients' needs. China will likely continue to improve the efficiency of environmental treatment, but more significantly, the wastewater treatment business model will shift from "staking out" (when one gives the lowest price to win the bid before designing the operation) to holistic considerations of equipment, investment, and operational costs in advance. The right approach may not be one-size-fits-all, but a variety of advanced and innovative methods for the different challenges of municipal waste and industrial waste.

## CHALLENGES IN SCALING: INCONSISTENT MUNICIPAL CONTENT

The inconsistencies in China's municipal wastewater treatment remain a major challenge. Conventional wastewater treatment processes regard sludge as a waste byproduct, rather than a resource. Sludge treatment demands an intensive dewatering process that mixes in chemicals to reduce the sludge's water content by 50 to 70 percent. Wastewater facilities treat the dehydrated sludge only partially, and certainly not enough to use as compost. Instead, the product is typically taken to composting facilities for further processing or, more commonly, to landfills and incinerators.

Dewatering organic sludge waste is typical in urban areas because it is cheap and versatile for varying levels of organic and water content. However, dewatering can hardly satisfy China's new regulations for treatment and water pollution action plan goals.

One commonly touted method for treatment and pollution reduction is anaerobic digestion (AD) of sludge, which extracts methane gas from wastewater. But AD treatment often fails to meet expectations due to the large fluctuations in organic matter in China's municipal wastewater. In many urban areas, wastewater and stormwater are combined in the drainage system before reaching treatment facilities. This leaves the concentration of organic matter in the wastewater too low to meet the need for continuous AD—which in turn leads to inconsistent biogas production. At present, AD is mainly used for specific industries that produce organic-rich wastewater, such as the food and beverage industry, the livestock industry, and the petrochemical industry. Nationwide, municipalities have not yet scaled up the use of AD for biogas production. Resource recovery efforts by industries offer valuable insights into China's urban sludge transition, but also have their own unique challenges.

## RESOURCE RECOVERY ON THE INDUSTRIAL LEVEL

Beyond municipal wastewater, resource recovery can play a significant role in alleviating the environmental impact of China's industrial waste. As industrial waste pollution is considerably more diverse and hazardous in chemical content, its treatment requires more advanced technologies, often highly customized and varied based on the industry's water quality and customers.

Wastewater in China's oil and gas industry is oil-rich. This qualifies it as a "hazardous waste," whose disposal requires expensive certificates and qualifications for operators. This waste is often sent to incineration plants or landfills, a short-sighted and unsustainable solution for rapidly urbanizing China. The current cost of treating hazardous waste is around 3,000–5,000 RMB ($440–$740 USD) per ton and still climbing. Not only is this a very high cost, but building incineration plants often encounters citizen protests while landfill capacity is increasingly limited.

Ultimately, there is both a business case and environmental case for the recovery of hazardous waste in China. New technologies can recover water from industrial wastewater through membrane separation, while extracting and separating oil and inorganic solids. Once extracted, the heavy oil can be recycled for further refining and reuse. This significantly reduces the volume of wastewater; as well, with most hazardous material removed, the water can undergo subsequent treatment processes to reach an appropriate level of toxins for safe disposal.

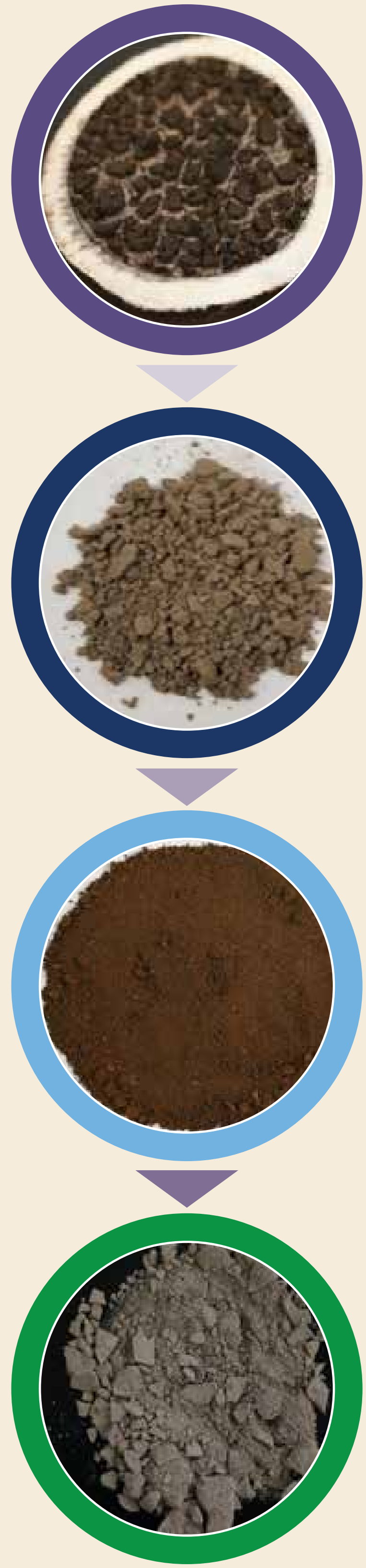
The highly varied content of municipal and industrial wastewater poses a complex challenge for treatment—there is certainly no single solution. But today's conventional treatment processes will not meet the needs of existing customers and new regulation. China will need a variety of novel, advanced technologies to enhance the capacity of wastewater treatment. From AD to membrane separation techniques, these new methods will play an increasingly critical role in China's waste-to-energy transition.

## MORPHOLOGY OF OIL SLUDGES

From top to bottom: bottom sludge from oil tank, oil sludge after plate pressure filtration, oil sand, and drilling mud (water content is 30–80%)

## SOLIDS LEFT AFTER WATER AND OIL EXTRACTION

Water content is less than 10%



## EXTRACTED OIL AND WASTEWATER

Top layer includes diesel and heavy oil;
bottom layer is wastewater

## A SPECIAL THANK YOU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