W A T E R E N V I R O N M E N T R E S E A R C H F O U N D A T I O N

FACT sheet

A Technical Look at Energy and Resource Recovery from Wastewater Residuals

Domestic wastewater commonly contains organic matter, nutrients, and minerals suspended in a water medium. These products of wastes are potentially valuable resources, both as energy and as reusable compounds. When energy costs are soaring and elements like phosphorus are becoming increasingly scarce, the recovery and renewability of these resources become economically and ecologically attractive.

Many technologies are currently able to recover energy and/or resources from wastewater residuals or sludge, as detailed in the *State of Science Report: Energy and Resource Recovery from Sludge,* published by WERF for the Global Water Research Coalition. The report provides technical, capital cost, and operating and maintenance (O&M) cost information, to the extent possible for each technology.

Energy recovery from sludge

Energy recovery technologies include processes which produce different energy products. The most common is sludge-to-biogas (methane gas) processes. The production of biogas from anaerobic digestion is an established process, but one that is not fully implemented at all the wastewater plants capable of using this process.

In addition, new technologies pre-treat sludge solids to break down the cells and promote biotransformation to methane. These technologies include thermal hydrolysis (heating the sludge under high pressure), and an array of cell destruction methods, i.e., ultrasonic treatment, ozone, pulse electrical fields, and mechanical disintegration. Some of these technologies are trademarked or patented by the vendor. These processes include Microsludge™, BioThelys®, and Cambi®. The Cambi® process was studied in pilot and lab-scale digesters before installation at the Bran Sands Regional Sludge Centre, UK. Results confirm the process improved biogas conversion.

Sludge can be converted to energy-rich gases (consisting of mainly of CO and H_2 gas) by sludge-to-syngas processes. These technologies are based on pyrolysis and gasification. First, the organic rich sludge solids are heated (600°C or less) in the absence of air, producing a carbon-rich substance called char. The char is gasified in the presence of air to produce syngas which can generate electricity or heat.

- The KOPF process has been used in Germany and the EBARA process is operated at six facilities in Japan.

Sludge can also be converted to oil, which generates heat or electricity, or can become feedstock for biofuel.

- Two commercial processes—EnerSludge™ and SlurryCarb™—have been demonstrated in Australia, Canada, and Japan.
- A new full-scale facility will be started in California in 2008.

An emerging sludge-to-liquid process is supercritical water oxidation which involves heating at temperatures around 374°C, high pressure, and pure oxygen. This process converts 99.99% of the chemical oxygen demand in sludge to carbon dioxide. The process is complex, requiring cryogenic oxygen equipment, and is currently expensive.

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Resource recovery from sludge

Diverse technologies recover phosphorus, nitrogen, or volatile acids. Other technologies can produce inert building materials. There are other innovative ideas like upgrading biosolids pellets as a renewable source of inoculum for bio-hydrogen gas production, or recovering bio-pesticides from sludge.

Phosphorus recovery processes have been in use for a while, and have a 60-70% (or higher) efficiency.

- Crystalactor® technology uses sand as a seed material for crystal development. Sludge is treated with lime to a pH of 8. Calcium phosphate pellets form around the sand particles and are removed from the reactor. The process has been applied in the Netherlands but is not yet able to produce calcium phosphate for equal or less than the market price.
- Phostrip® technology recovers calcium phosphate from a sidestream process using phosphorus-enriched sludge. The sludge sidestream goes into anaerobic stripper tanks dosed with acetic acid. After the phosphorus-rich supernatant liquid is revoked from the sludge, it is treated with lime to precipitate phosphorus as calcium phosphate. This process has been used at several plants in the United States.

The OSTARA process recovers struvite (crystalline magnesium ammonium phosphate hexahydrate) from a phosphorus-rich sludge sidestream using magnesium chloride. The process requires harsh chemicals (i.e. sulfuric acid, sodium hydroxide), which makes this process less acceptable than processes using lime.

- A full-scale facility is in operation at a wastewater treatment plant in Edmonton, Canada.

Several types of building products can be made from inert materials recovered from sludge. These products include lightweight aggregates, brick, cement, and glass. Typically, the inert material consists of ash, a by-product from sludge incineration, or glass aggregate, an end-product of thermal solidification.

- GlassPack® vitrification process uses the organic fraction of sludge as a renewable energy source to produce an inert glass aggregate. It has multiple reuse outlets and is approved by the Illinois EPA and Wisconsin DNR for beneficial reuse.

Influence of market and regulatory drivers on the fate of the sludge end-product

The technologies for energy and resource recovery must be affordable and cost effective. This is currently not always the case. Some demonstration projects have failed because of the high capital and operating and maintenance (O&M) costs. Examples of such projects are certain phosphorus recovery and building material production processes.

The social acceptance of any technology depends on the characteristics of additives used and the products generated by that process. Chemical use may be required in certain resource recovery processes, but they may not always be the best options in term of health protection and life cycle impacts (energy use and emissions during production and transportation). For example, most current technologies for phosphorus recovery are based on extraction with sulfuric acid, a highly corrosive and potentially harmful chemical. In addition, technologies with high potential for pollutant emissions, either upstream or on-site, will have less public acceptance. Technologies involving several process units are generally viewed as less desirable since they are complex processes, which require more material and energy for production, greater land consumption, and higher capital and O&M costs, than simpler processes.

Social, economic, and environmental performance (triple bottom line assessment)

A triple bottom line (TBL) assessment shows that, in terms of energy recovery overall, sludge-to-biogas and sludge-to-syngas processes are the most suitable options. For phosphorus recovery, the technologies using less harmful chemicals like lime are the best options. Thermal solidification for brick production appeared as a better option compared to slag and artificial lightweight aggregates production.

A cursory TBL assessment cannot evaluate all technologies in depth, and should therefore be used as general guide rather than as a definitive review. Indeed, many key information requirements are missing for some of the technologies, leading to incomplete or subjective assessment. The limits of the assessment are discussed in the report.

Social, Economic, and Environmental Performance

Process	Social	Economic	Environmental
Sludge to Biogas	+	0	+
Sludge to Syngas	+	+	+
Sludge to Oil	+	-	+
Sludge to Liquid	-	-	+

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