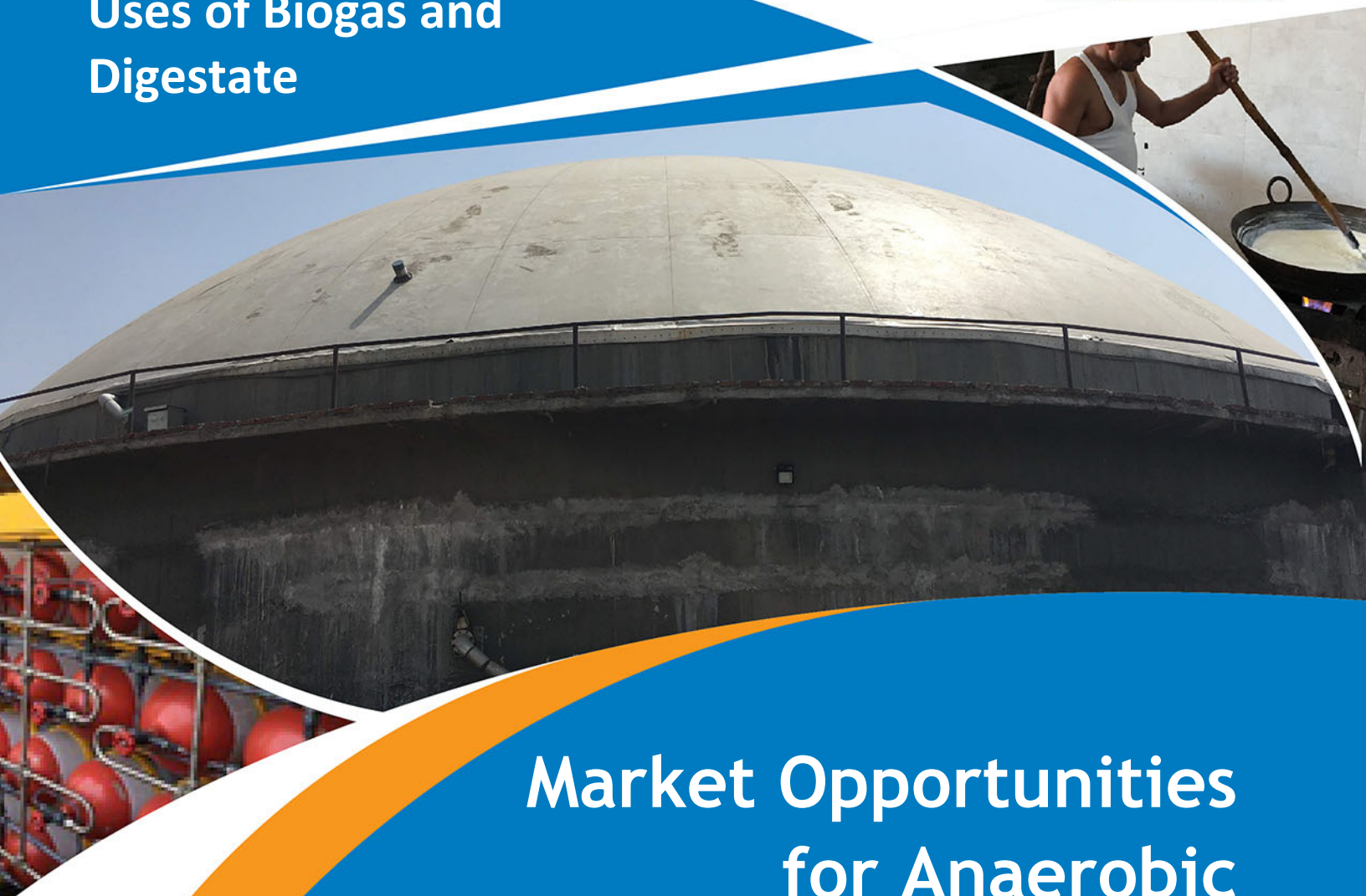
Section 1
Uses of Biogas and Digestate



Market Opportunities for Anaerobic Digestion of Livestock and Agro-Industrial Waste in India

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1. Uses of Biogas and Digestate

Anaerobic digesters process feedstock to produce biogas, which consists primarily of methane (40–60 percent) and carbon dioxide. It also includes moisture, hydrogen sulfide, nitrogen, and oxygen. Biogas can be used as an energy source for multiple purposes, including cooking, heating, cooling, transportation, and electricity. Biogas from anaerobic digesters must be cleaned to remove moisture, hydrogen sulfide, nitrogen, and oxygen to be suitable for some uses (e.g., cooking fuel). Additionally, it needs to be upgraded by removing carbon dioxide for other uses (e.g., transportation fuel).

Digestate is the leftover material from anaerobic digestion (AD) after the feedstock has gone through the digestion phase. High solid ("dry") AD systems generate high solid content digestate while low solid ("wet") AD systems generate low solid content digestate. The quality of the digestate depends on the quality of the feedstock. If the feedstock is clean from contamination (toxins, plastics, glass, etc.), the resulting digestate is cleaner and has a better market potential.

1.1 Biogas Use

Cooking

Upgraded or non-upgraded biogas is considered a clean and sustainable cooking fuel, depending on the use. In India, wood-fired stoves and dried cow manure burning are being replaced with biogas cook stoves, improving sanitation and indoor air quality for millions of people. These gas cooking stoves can be connected to small anaerobic digester systems or fueled by bio-compressed natural gas (bio-CNG) in cylinders. Most gas cooking stoves in India currently operate with individual cylinders, while some large cities (e.g., Delhi) have gas pipelines that connect to the stoves. The biogas needs to be upgraded to be fed into such pipelines or compressed into bio-CNG cylinders.

Heating

Biogas can be used directly or with very little conditioning for heat generation and thermal applications. Examples of such uses include:

- Furnaces, dryers, and kilns can use biogas as a replacement for or supplement to conventional fuels in several manufacturing sectors, including cement, brick and ceramics, iron and steel, and wood products.
- Boilers can use biogas as a fuel to produce steam or hot water (e.g., the steam produced by boilers can be used for space heating, process heating, or electricity generation via a steam turbine). Bio-CNG can also be used to fuel furnaces and boilers, or for heating.

Cooling

Small scale famers in India often do not have access to refrigeration technologies, leading to quantities of spoiled agricultural products. Biogas can replace the use of kerosene or liquefied petroleum gas, and be used for cooling as a heat source for vapor absorption refrigerator systems. These systems use locally available farm-based renewable energy sources, including biogas, to run the systems at a much lower operating cost than using diesel or grid electricity. Developed to power cold storage systems to extend the life of perishable agricultural products (e.g., milk, fruits, vegetables), these systems improve economic conditions for farmers in rural areas of India.

Transportation

Biogas that is upgraded to a higher methane purity can be used interchangeably with conventional natural gas. Biogas needs to be upgraded to more than 90 percent methane to be considered useable as a transportation fuel. Biogas can be used as a vehicle fuel when upgraded and compressed into bio-CNG, or liquefied into

liquefied natural gas (LNG). Bio-CNG and LNG production are economical only at medium- or large-scale AD facilities due to the costs associated with upgrading technology.

Some cities in India have CNG-powered public transportation vehicles. For example, Delhi currently has over 10,000 CNG buses, and the number of CNG vehicles in India has been increasing. The Government of India plans to develop infrastructure to increase the number of CNG plants, pipelines, and filling stations. It announced an initiative in 2018 to reduce India's dependence on oil and gas imports by producing bio-CNG for transportation fuel using agricultural residues, cattle dung, sugarcane press mud, municipal solid waste, and sewage treatment plant waste.

Electricity Generation

Biogas can be used as a fuel in internal combustion engines or combustion turbines to generate electricity. The electricity can be used to cover onsite energy needs or sold to the local electricity grid. For electricity production, biogas may or may not be additionally cleaned or conditioned, depending on the energy recovery unit installed. The following examples are systems for electricity generation from biogas:

- Internal combustion engines are the most common biogas utilization technology for small to medium-sized AD systems. These engines are available in various sizes, with electrical outputs ranging from a few kilowatts to more than 3.0 MW per unit.
- Gas turbines are generally larger than internal combustion engines and are available in sizes from 1 MW to more than 10 MW. Although smaller gas turbine units or "microturbines" (less than 1 MW) have been used, they are not normally the primary generating unit. Gas turbines are available as modular and packaged systems.
- Combined heat and power (CHP) or cogeneration systems generate electricity and capture waste heat to provide thermal energy. Thermal energy can be used for onsite heating, cooling, or processing needs; or piped to nearby industrial or commercial users to provide a second revenue stream for the project. CHP is often a better economic option for end users located nearby or for projects where the end user has sufficient demand for both electricity and waste heat.

1.2 End Uses of Digestate

Digestate can be used as a soil amendment, fertilizer, or value-added product, most often after post-processing (such as composting). Biogas digester effluents are primarily used as organic fertilizers in India. In some cases, AD systems may sell the digestate as a commercial soil amendment or fertilizer, which can increase the financial viability of the AD system. In the case of some feedstocks (e.g., distillery effluent), the digestate must be further treated or blended before it can be applied on land. In the United States, digestate is often used as animal bedding for cows. New innovations in value-added products such as biodegradable planter pots and building materials are being created from digested manure, providing additional income to the digester owner.

Care should be exercised when using digestate as a fertilizer due to the risk of contamination. The contamination type and level depend on the feedstock and the AD system. With manure and wastewater treatment sludge feedstocks, the biggest risk is pathogen contamination, which can cause serious health issues if applied on agricultural land. Contamination from heavy metals, plastics, and glass is also a challenge when feedstocks are sourced from municipal solid waste.