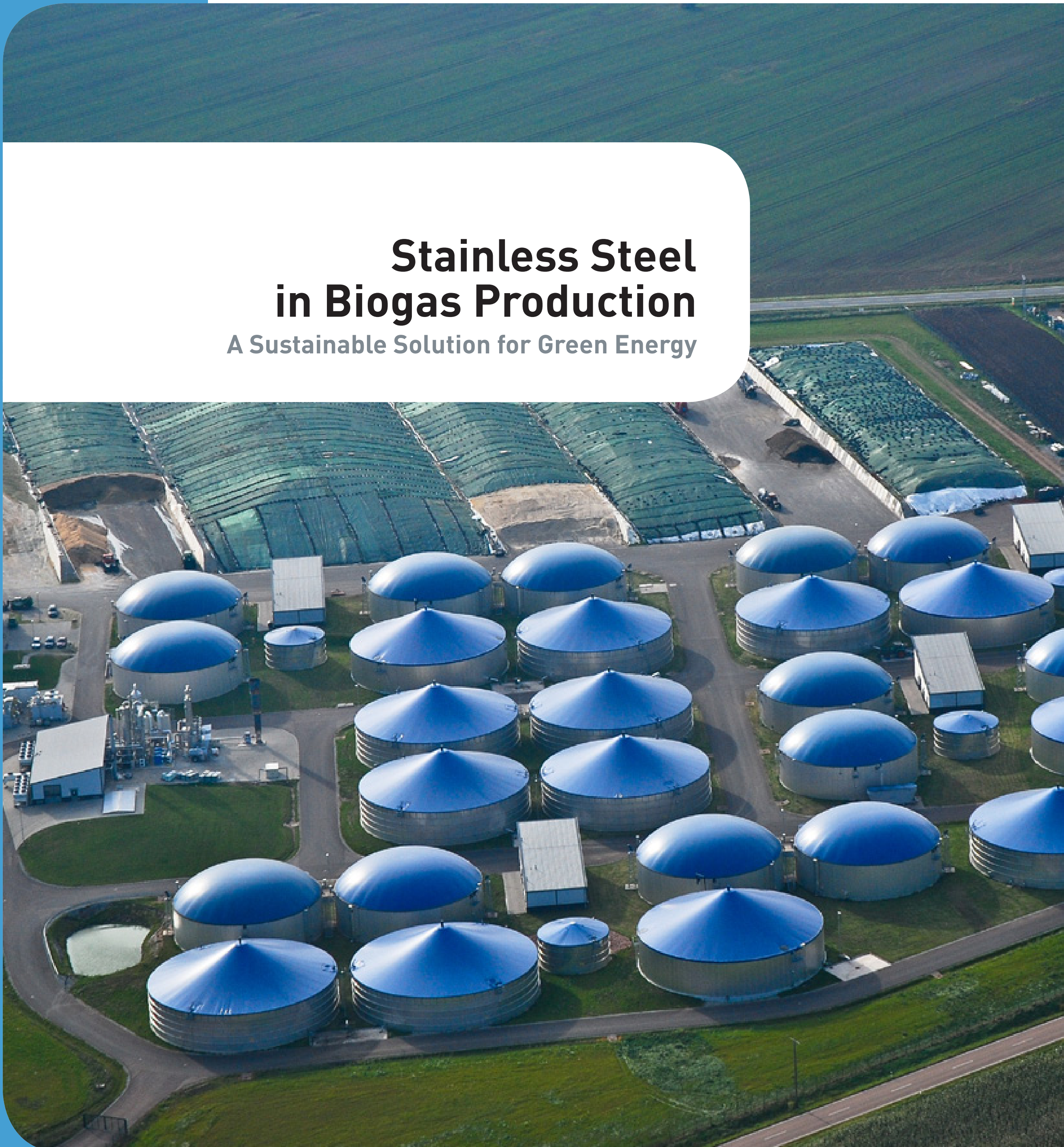
SUSTAINABLE STAINLESS

Stainless Steel in Biogas Production

A Sustainable Solution for Green Energy



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A Sustainable Solution for Green Energy

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introduction

The fact that climate change is occurring is largely undisputed among the global scientific community today. A large body of data including measurements of greenhouse gases in the atmosphere, meteorological records, polar ice melting data and clear changes in ecosystems support this conclusion.

Estimates from the International Energy Agency[1] (IEA) indicate that energy production from biomass and waste will nearly double between 2009 and 2035. The average growth rate is expected to be 2.5%. Energy from coal is expected to decrease markedly at an average rate of 1.4% a year over the same period.

Except for hydroelectricity, energy from biomass is among the cheapest forms of renewable energy (see Table 1). However, suitable sites for hydroelectric plants are limited and require huge initial investment.

Table 1: Range in costs of energy (US$/MWh)[2]

Energy source	Minimum cost	Typical cost	Maximum cost
Biomass	30	50-200	350
Solar	60	200-350	850
Geothermal	40	50-60	170
Hydroelectric	10	30-60	140
Ocean	120	190-220	320
Wind	40	80-120	230
Non-renewable		30-100	

When biomass is compared to non-renewable resources, the cost is already similar. It is reasonable to expect the cost of energy from biomass will fall as the technology matures.

As waste reduction is increasing in importance, the environmental protection agencies in many countries are seeking ways to reduce the amount of rubbish going to landfill and utilise its energy content. Biogas production from organic waste is attractive because:

- It produces biogas, which can be used to produce energy
- There is a relatively constant stream of organic waste available as a raw material
- The amount of rubbish going to landfill is reduced, mitigating a waste-disposal headache for the agencies responsible.
- Land can be dedicated to food production rather than the production of material for biomass systems.

WHAT MAKES STAINLESS STEEL A SUSTAINABLE MATERIAL?

Sustainability is defined in terms of the triple bottom line: People (social), Planet (environment) and Profit (economic).

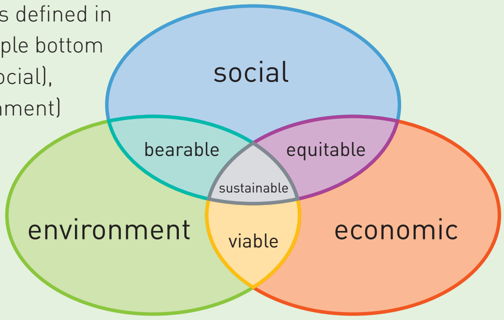

Figure 1: Sustainable development occurs at the confluence of its three constituent parts[3]

People

The material, in its use or in its production process, respects the human being, especially in terms of health and safety. A sustainable material does not harm the people working to produce it, or the people who handle it during its use, recycling and ultimate disposal.

Stainless steel is not harmful to people during either its production or use. A protective layer forms naturally on all stainless steels because of the inclusion of chromium. The passive layer protects the steel from corrosion – ensuring a long life. As long as the correct grade of stainless is selected for an application, the steel remains inert and harmless to the people who handle it and the environment.

These characteristics have made stainless steel the primary material in medical, food processing, household and catering applications.

Planet

The emission footprints of the material, especially those related to carbon, water and air, are minimised. Reuse and recyclability are at high levels. The material has low maintenance costs and a long life, both key indicators that the impact of the material on the planet is at the lowest levels possible.

The electric arc furnace (EAF), the main process used to make stainless steels, is extremely efficient. An EAF has a low impact on the environment in terms of both CO2 and other emissions. The EAF is also extremely efficient at processing scrap stainless, ensuring that new stainless steel has an average recycled content of more than 60%.

Stainless steels are easily recycled to produce more stainless steels and this process can be carried on indefinitely. It is estimated that about 80% of stainless steels are recycled at the end of their life. As stainless steel has a high intrinsic value, it is collected and recycled without any economic incentives from the public purse.

Profit

The industries producing the material show long-term sustainability and growth, provide excellent reliability and quality for their customers, and ensure a solid and reliable supply-chain to the end consumer.

Choosing the right stainless steel grade for an application ensures that it will have low maintenance costs, a long life and be easy to recycle at the end of that life. This makes stainless an economical choice in consumer durables (such as refrigerators and washing machines) and in capital goods applications (such as transportation, chemical and process applications).

Stainless steels also have better mechanical properties than most metals. Its fire and corrosion resistance make stainless a good choice in transportation, building or public works such as railways, subways, tunnels and bridges. These properties, together with stainless steel's mechanical behaviour, are of prime importance in these applications to ensure human beings are protected and maintenance costs are kept low. Stainless also has an aesthetically pleasing appearance, making it the material of choice in demanding architectural and design projects.

Taking into account its recyclability, reuse, long life, low maintenance and product safety, the emissions from the production and use of stainless steels are minimal when compared to any other alternative material. A detailed and precise analysis of the sustainability of stainless steel makes the choice of stainless a logical one. This might explain why, as society and governments are becoming more conscious of environmental and economic factors, the growth in the use of stainless steel has been the highest of any material in the world.

HOW A BIOGAS PLANT WORKS

Biogas is typically produced from organic waste such as sludge from waste water treatment plants, manure, food industry waste, and agricultural waste. Many large farms and waste water treatment plants are equipped with their own biogas production plants. Figure 2 shows how a typical biogas plant operates. The actual process depends on the size of the plant and the equipment manufacturer.

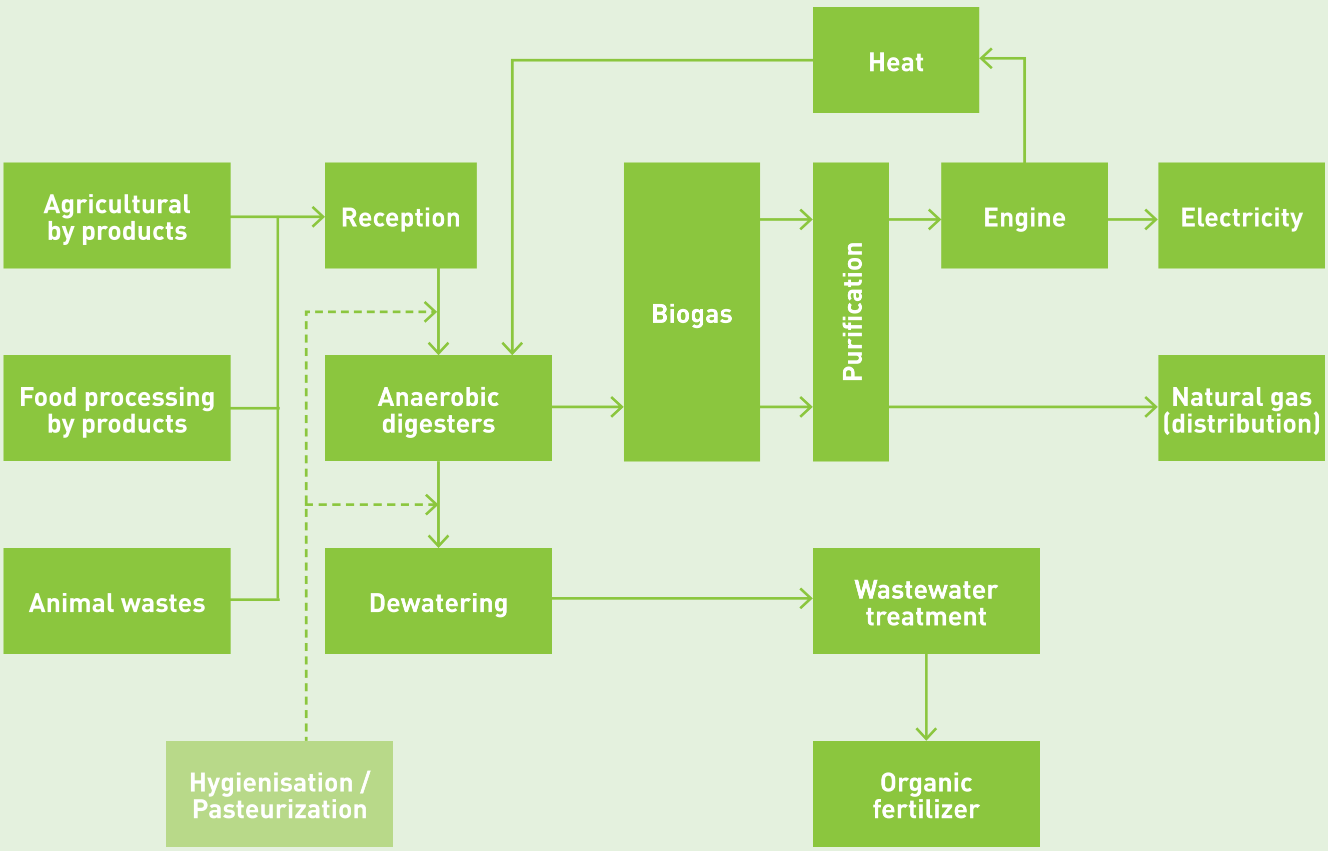

Figure 2: Overview of a typical biogas production plant

Digestion

Once the waste reaches the plant it is often shredded. The waste is then fed into the anaerobic digester tanks which are the core of the plant. Bacteria transform the organic material into biogas in three steps:

1. Acidogenic bacteria break the waste down into simpler molecules. Ammonia, CO_2 and hydrogen sulphide (H_2S) are by-products of this step.
2. Acetogenic bacteria digest the simple molecules to produce CO_2, hydrogen and acetic acid.
3. Methanogens act on the acetic acid to produce biogas. The biogas is a mixture of methane (55-70%), CO_2 (20-40%), water vapour and some residual (often corrosive) gases.

Digestion is optimised by keeping the temperature at about 40°C and the pH level between 5.5 and 8.5. The system can be self-powered by the exothermic digestion process, though usually additional heat is provided by burning some of the biogas.

Sometimes substances in the inlet and/or outlet areas must be heat treated so that germs and bacteria are rendered harmless and do not spread. Two different methods of heat treatment are used:

- Hygienisation: the material is heated to 70°C (158°F) and held at that temperature for 60 minutes.
- Pasteurisation: the material is heated to 133°C (271.4°F) and held at that temperature for 20 minutes.

These high temperature treatments create a hostile environment. Stainless steel is among the few materials that can withstand the aggressive gases produced.

Energy production

In the simplest case, biogas fuels an engine, which in turn drives a generator to produce electricity. The heat generated by the engine is usually used within the plant to maintain the digester at the optimum temperature, to dry hay, or to heat offices.

The biogas may also be cleaned, then fed into a natural gas distribution system or compressed and used to power vehicles.

Residual waste

Waste from the biogas plant is around 50% of the input mass. It is easy to dispose of and is often used as fertiliser.

STAINLESS STEEL IN A BIOGAS PLANT

Corrosive compounds such as H_2S and ammonia are unavoidable by-products of the biogas production process. All equipment in the digester tanks comes into contact with these corrosive elements. Unless corrosion-resistant materials are used, damage to equipment will occur. It is essential to avoid breakdowns, as restarting a digester is a long and delicate operation. At the same time, waste continues to be delivered to the plant.

Properly specified stainless steels can withstand the corrosive materials in a biogas plant. This is why stainless steel is typically utilised in:

- Digesters
- Pumps and valves
- Agitators
- Pipes and fittings
- Purification applications.

Stainless steel in digesters

Concrete is currently the most widely used material to build digesters because of its cost advantages and flexibility. However, construction must be relatively large scale to be cost effective and requires several heavy machines. Construction of concrete digesters in typical biogas plant is shown in Figure 3.

Figure 3: Construction of concrete digesters in typical biogas plant

During operation, regular maintenance is very important to prevent leakages. Leakages of gas, water and odour from a digester can cause serious problems for the plant. It is hard to avoid corrosion in concrete digester tanks, even though a special coating system is utilised.

Figure 4: Inside view of a concrete digester after operation

These problems can be avoided if a stainless steel tank is used. The thickness of stainless steel plate for a biogas tank is less than 5 mm and it is very easy to construct. Stainless steel biogas tanks are assembled from top to bottom and lifted into place using a simple system.

Stainless steel reduces construction time and logistic costs. It has excellent corrosion resistance against H_2S or ammonia and this makes maintenance easier.

Figure 5: Construction of a stainless steel digester tank[4]

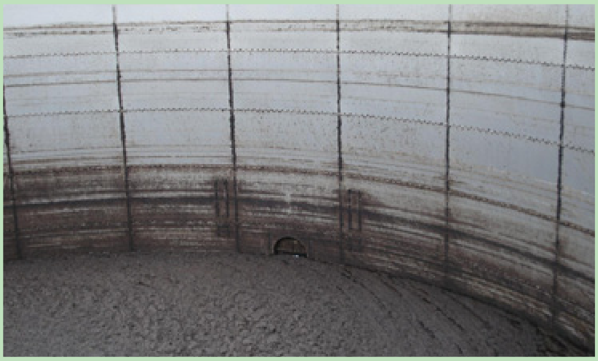

Figure 6: Inside view of a stainless steel digester tank after operation[5]

Stainless steel has many advantages in this application including:

- Lower construction costs: a typical tank can be completed within a week.
- Minimal logistics: makes it possible to construct a biogas plant in almost any area.
- No need for repairs thanks to the corrosion resistance of stainless steel.
- Gas and water tightness: joints are easy to keep watertight; holes are easy to drill; and gas leakage is prevented.
- Residual value: at the end of its useful life, the stainless steel has a scrap value.

As well as being used to make the digester, the manure, water and residue storage tanks also utilise stainless steel. Digester tanks are often covered by insulation, as shown in Figure 7.

Pumps and valves

Pumps and valves handle slurries, fluids and gases which contain corrosive materials.

Agitators

Agitators help to homogenise the temperature of the biomass and reduce crust formation. They are in constant contact with corrosive elements.

Pipes and fittings

Stainless steel is utlised for pipes and fittings in biogas plants for its corrosion resistance and excellent formability. Its heat-transfer coefficient is also better than that of plastics. Grade EN 1.4404/AISI 316L is preferred for these applications.

Figure 8: Inside view of a stainless steel digester tank[7]

Figure 7: Interior view of stainless steel storage tank (left) and exterior view of storage an digester tanks[6]

Purification

The biogas produced by the system contains many impurities (usually H_2S) and water vapour, both of which are undesirable. Hydrogen sulphide is poisonous and smells of rotten eggs, while water vapour reduces the efficiency of biogas when it is burnt to generate electricity. A biogas dehumidifier provides efficient dehumidification and is easy to install and maintain.

In most cases, the dehumidification process takes place before the hydrogen sulphide is removed. Stainless steel (grade EN 1.4404/AISI 316L) is often used for the parts of dehumidifier systems which come into contact with wet biogas as it can withstand the corrosive effects of the hydrogen sulphide it contains.

Figure 9: Examples of biogas dehumidifier systems[8]

CASE STUDIES

Saxony-Anhalt biogas plant – Könnern, Germany

One of the world's largest biogas plants is located in the Könnern industrial zone in Germany. It was constructed by WELTEC BIOPOWER GmbH. The plant has 16 digester tanks (each 6.3 metres high and 25.0 metres in diameter) which are divided into four modules. Over 120,000 tonnes of liquid manure and maize are used as raw materials. This is more than five times the capacity of a typical biogas plant.

The plant produces up to 15 million cubic metres of biological natural gas each year which is refined from raw biogas. The digester tanks are made of stainless steel grade EN 1.4301/ AISI 304.

Figure 10: Aerial view of the Saxony-Anhalt biogas plant[9]

Wuxi Kaipu CNG System – China

One of the first biogas plants in China, the Wuxi Kaipu CNG System was commissioned in 2010. The plant processes 15,000 Mt of pig manure, 1,500 Mt of rice straw and 20,000 Mt of organic waste water. It has two 3,560 m^3 digesters and produces 2,800 MWh/year. Stainless steel grades EN 1.4301/ AISI 304 and EN 1.4571/AISI 316Ti are used for the digester tanks and other components.


Figure 11: Digester tank in the Wuxi Kaipu CNG System[10]

In China, it is not yet common practice to feed privately generated energy into the electricity grid. The usual approach is to either generate bio-methane and use it directly, or to use the generated energy directly.

Frankfurt Hahn Airport – Germany

Since 2005, Frankfurt Hahn Airport has met a large part of its power and heat needs with biogas. A gas-fired co-generation plant, with an electric output of over 600 kW, simultaneously produces electricity and heat.

Two digesters with a total capacity of 1,525 m^3 deliver 4,560 MWh of electricity and 6,700 MWh of heat each year. Stainless steel grade EN 1.4301/AISI 304 is used for the part of the digester which is in contact with the liquid, while EN 1.4571/AISI 316Ti is used for the upper part where the gases accumulate. The power is fed into the airport's grid while the thermal energy is made available to a local district heating system. Grass clippings from the airport is one of the raw materials used in the system. Regional agricultural production and animal manure are the other sources of feedstock.


Figure 12: Frankfurt Hahn Airport's co-generation plant showing a pre storage tank (top left), external view of the plant (bottom) and inside of a tank (top right)[11]

Biogas in Korea

The Korean government is promoting biogas production and several biogas plants were established before 2010. Plant makers are classified into two different groups depending on the scale of production. Big companies, which have relatively large biogas plants, process food waste from big cities. Several government departments also have plans to introduce up to 500 biogas plants.


Figure 13: Bousung Biogas Plant[12]

The Bosung Biogas Plant, which was constructed in 2010, is the one of the largest government plants. It can produce 730 MWh/year using resources such as animal and food waste. Stainless steel grade EN 1.4301/AISI 304 is used for the fermentation tank at this plant. The plant was constructed by the local Korean company Daewoo Engineering & Construction Co.

Shinko Bio Arc Project, Japan

The Shinko Bio Arc Project in Japan was completed in 2011 and is operating commercially. The main purpose of this project is to create a closed recycling loop within the food production and disposal chain.

Figure 14: Stainless steel digester tanks at the Shinko Bio Arc[13]

The Bio Arc can treat 160 tonnes of food and 200 tonnes of other soluble waste each day. The plant, which was designed by Lipp GmbH, contains four digester tanks (each 10 metres tall and 15 metres in diameter) and two generators which can deliver 800 kW of electricity. Cladding made from thin, laminated stainless steel (EN 1.4571/AISI 316Ti) and galvanised steel was used to construct the tanks. The unique fixing system achieves high corrosion resistance, easy construction and gas and water tightness without welding or bolting.

CONCLUSION

Biogas is one of the most attractive sources of renewable energy. It mitigates the growing problem of waste disposal, is cost competitive without subsidies, and produces energy which can be used locally or fed into the electricity grid.

Stainless steels improve the reliability and efficiency of biogas plants. Their performance has already been demonstrated, making them the material of choice for biogas processing equipment.

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