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**Anil Bhatta** Carbon& Clean Energy Solutions (CCES)

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제1호 : 파리협정 후속협상의 내용과 동향
(이재형 고려대학교 법학전문대학원 교수)

제2호 : 대기오염물질과 온실가스의 통합관리
(김승도 한림대학교 교수)

제3호 : 기후변화 시대 재생에너지 확대를 위한 에너지 규제 패러다임의 변화: 미국 뉴욕州 Reform the Energy Vision(REV) 개혁을 중심으로
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(홍영식 세종대학교 국정관리연구소 행정관리센터장)

제5호 : Role of Waste to Renewable Energy Projects in achieving Sustainable Development Goals(SDGs)
(Anil Bhatta Carbon& Clean Energy Solutions (CCES))

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# Role of Waste to Renewable Energy Projects in achieving Sustainable Development Goals(SDGs)

Anil Bhatta Carbon& Clean Energy Solutions (CCES)

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# I. Executive Summary

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# Ⅰ. Executive Summary

The Sustainable Development Goals (SDGs) are targets that needs to be met by 2030, meaning, the governments around the world have approximately 12 years to take necessary action to achieve this goal. Reliable, clean and affordable energy has the most important role to play in achieving SDGs as energy is essential to sustainable development. Waste is an unavoidable product of our society; waste volumes are increasing rapidly, even faster than the rate of urbanization both in developed and developing countries. Waste has an adverse impact on human health and the environment. Methane emissions pertinent to the waste contribute in global warming and climate change. Waste to renewable energy technology in particular Anaerobic Digestion (AD) biogas technologies are well placed to address global waste challenges at a greater extent and help achieve some of the key SDGs mainly **SDG 2** - End hunger, achieve food security and improved nutrition and promote sustainable agriculture; **SDG 7** - Ensure access to affordable, reliable, sustainable and modern energy for all; **SDG 8** - Promote inclusive and sustainable economic growth, employment and decent work for all; **SDG 11**- Make cities and human settlements inclusive, safe, resilient and sustainable; **SDG 13** - Take urgent action to combat climate change and its impacts; **SDG 5** - Achieve gender equality and empower all women and girls; and **SDG 15** - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. This paper explores the role of waste to renewable energy projects in achieving Sustainable Development Goals (SDGs).

# Ⅱ. Introduction: A broad look at emerging waste issues and Sustainable Development Goals (SDGs)

# Ⅱ. Introduction: A broad look at emerging waste issues and Sustainable Development Goals (SDGs)

## 2.1 Emerging Waste Issues

The worlds' cities generate 1.3[1] billion tonnes of solid waste per year that is expected to rise to 2.2 billion tonnes by 2025 as population is expected to rise. Just to put things into perspective, in 1960, the world population was only 3 billion as compared to the world's current population, which is 7.6 billion[2] and growing rapidly. Meaning, in the last 58 years the world population has increased by more than double, consuming significant amount of resources and generating waste at an unprecedented rate.

At present, the size of major global cities is increasing fast, which in turn is generating unmanageable municipal solid waste (MSW). In fact, globally, waste volumes are increasing rapidly, even faster than the rate of urbanization. Solid waste is correlated to the urbanization and economic development of a country. As countries urbanize, their economic wealth surges. As standards of living and disposable incomes increase, consumption of goods and services increases, which results in an equivalent increase in the amount of waste generated. Furthermore, people are migrating from rural to urban areas in almost every country. In 1950, only 30% of the world's population lived in urban areas; in 2014 it was 54%; and by 2050 it is forecasted to become 66%[3]. The percentages of people migrating from rural to urban areas are around 80% in the Americas, and over 70% in Europe and Oceania, and 48% in Asia and 40% in Africa. With the rapid growth in population and urbanization, waste generation rate is expected to double over the next twenty years, particularly, in lower income countries.

1) World Bank, 2012
2) Worldometers 2018
3) Wilson & Velis 2014

|  |  |
| --- | --- |
| **Fig 1: River waste dumping (Photo Source: The Fifth Estate Australia)** | **Fig 2: Open air waste dumping (Photo Source: The World Bank)** |

Along with the increasing global population and urbanization, the negative impacts of solid waste on public health and the environment are growing fast. For example, inadequate waste disposal practice results into soil, water and air pollution, and untreated waste can cause serious health problems. Other issues caused by mismanaged waste disposal that negatively impact people include landscape deterioration, local water and air pollution. Similarly, uncollected solid waste at the local level contributes to flooding, air pollution, and public health impacts such as respiratory ailments, diarrhea and dengue fever. The available scientific evidence on the waste-related health effects is not conclusive, but suggests the possible occurrence of serious adverse effects, including mortality, cancer, reproductive health, and milder effects affecting well being[4].

Importantly, solid waste is a large source of methane, a powerful Greenhouse Gas (GHG) that contributes to global warming and climate change (discussed in the later sections). Waste management is a demanding and challenging undertaking globally, with important implications for human health, environmental preservation, sustainability and economy. Therefore, managing waste adequately and in an environmentally sound way is therefore important for public health, environment, economy and climate mitigation reasons.

4) WHO 2015

## 2.2 Sustainable Development Goals (SDGs)

The United Nations (UN) Sustainable Development Goals (SDGs) which came into effect on 1 January 2016 is a landmark agreement by all countries on a blueprint for a better future. The SDGs is a collection of 17 global goals that covers major global issues such as climate change, energy, poverty, hunger, education, health, gender equality, water sanitation, social justice, urbanization and environment and it guide efforts towards tackling and ending these issues by 2030.


**Fig 3: Sustainable Development Goals (Source: UNDP)**

All government members of the United Nations have agreed to meet the SDGs along with the NGOs, cities, industries, businesses and civil-society groups. This signifies that all members of the global society be it government or businesses have the ability to act and bring the positive change through cooperation. SDGs were developed to succeed the Millennium Development Goals (MDGs) that ended in 2015. It is important to note that SDGs are seen as a part of governments' policies regardless of development status of a county. The SDGs framework doesn't differentiate between "developed" and "developing" counties (unlike the MDGs). The SDGs apply to all countries whether it is a developed country or a developing country. Some of the goals such as Goal 13 (i.e. climate action), Goal 7 (i.e. Affordable and Clean Energy) are global challenges and are required massive action from both developed and developing countries whereas other goals such as Goal 1 (No Poverty), Goal 2 (Zero Hunger) are targeted more towards low-income countries.

A part of the good news is that some of the solutions and innovations required to achieve these goals are already available. For instance, waste to renewable energy technologies are well placed to address global waste challenges at a greater extent and at the same time help achieve some of the key SDGs.

As stated in the earlier section of this paper, management of waste is a demanding and challenging undertaking globally. However, if we look at this global challenge as an opportunity, we can harness opportunities from the burgeoning waste problem. For instance, if we consider biodegradable wastes in particular, they are abundant in both developed and developing countries. Such biodegradable wastes can be found in food waste from homes, restaurants, shops, industrial production, agricultural wastes from animal husbandry, crop cultivation, and food production (such as dairy); and sewage sludge from wastewater treatment etc., both at city and local community level. All of these wastes emit methane; however, can be collected to produce renewable energy and heat.

Aside from the governments of all the signatory countries, appropriate actions and support from all community sectors, global cities and industries are vital in achieving SDGs. This paper explores the role of waste to renewable energy projects implemented by industries and communities in achieving Sustainable Development Goals (SDGs).

The key two global challenges that require significant actions from both developed and developing countries - SGD 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) are central to the discussion of this paper, therefore, a brief summary of these two important goals are outlined below:

### Goal 7: Affordable and Clean Energy

Goal 7[5)] guides efforts in investing in clean energy sources to ensure universal access to affordable electricity by 2030. Targets for 2030 include access to affordable and reliable energy while increasing the share of renewable energy in the global energy mix. This would involve improving energy efficiency and enhancing international cooperation to facilitate more open access to clean energy technology and more investment in clean energy infrastructure. Sustainable Development Goal 7 contains three targets as outlined in the table below

5) UNDP: http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html)

**Table 2.2.1: SDG 7 Targets (SOURCE: SDG Compass)**

| Targets | Description |
|---|---|
| Target 7.1 | By 2030, ensure universal access to affordable, reliable and modern energy services. |
| Target 7.2 | By 2030, increase substantially the share of renewable energy in the global energy mix |
| Target 7.3 | By 2030, double the global rate of improvement in energy efficiency |
| Target 7.a | By 2030, enhance international cooperation to facilitate access to clean energy research and technologies, including renewable energy, energy efficiency, and advanced and cleaner fossil fuel technologies, and promote investment in energy infrastructure and clean energy technologies |
| Target 7.b | By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, particularly Least Developing Countries (LDCs) and Small Island Developing States (SIDS) |

## Goal 13: Climate Action

Goal 13[6] guides efforts in taking climate action to limit the increase in global mean temperature to two degrees Celsius above pre-industrial levels and it aims to mobilize $100 billion annually by 2020 to address the needs of developing countries and help mitigate climate-related disasters. Sustainable Development Goal 13 contains five targets as outlined in the table below.

**Table 2.2.2: SDG 13 Targets (SOURCE: Sustainable Development Knowledge Platform & SDG Compass)**

| Targets | Description |
|---|---|
| Target 13.1 | Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries |
| Target 13.2 | Integrate climate change measures into national policies, strategies and planning |
| Target 13.3. | Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning |
| Target 13.A. | Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible |
| Target 13.B. | Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities |

* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

6) UNDP: http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-13-climate-action.html

# Ⅲ. Waste management and Greenhouse Gas Emissions (GHG)

# Ⅲ. Waste management and Greenhouse Gas Emissions (GHG)

Waste is an unavoidable product of society, and one of the greatest challenges is to manage large quantities of waste in a sustainable way. Waste management is the activities and actions required to manage waste from its inception to its final disposal that includes, collection, transport, treatment and disposal of waste. One of the key reasons for managing waste is to reduce adverse effects of waste on human health and environment. Municipal Solid Waste (MSW) is managed in various ways across the world; however, some of the common methods are outlined below:

1. **Landfilling:** Landfilling is the deposit of waste into the land and it includes engineered design landfill sites. In general terms, landfilling is the disposal of waste in a managed way on land with or without pre-treatment of the waste. Landfilling of biodegradable wastes such as food waste, agricultural wastes etc results in the formation of landfill gas that contains methane. The methane emitted in landfill gas is considered as one of the main greenhouse gas impact of municipal solid waste.

2. **Incineration:** Incineration is a method of waste disposal that involves the combustion of waste. It is one of the widely used alternatives after landfilling where bulk municipal solid waste is burnt with or without pre-treatment of the waste. Incineration process may or may not recover the energy created during the combustion of the waste. The incineration process that recovers energy from the combustion process reuses the energy, for example, for power generation and heating purposes. Incineration process without energy recovery system do not harness the energy created during the combustion of waste and it allows the energy to get wasted in the environment. Greenhouse gas (GHG) is emitted during the waste incineration process that varies across waste incineration process.

3. **Mechanical–Biological Treatment (MBT):** MBT is a pre-treatment option for landfilling where municipal solid waste enriched in putrescible wastes (i.e. waste that contains organic matter capable of being decomposed by microorganisms) after the removal of materials for recycling is processed by a combination of mechanical and biological steps e.g. shredding, sieving, composting and sometimes anaerobic digestion to reduce the biological activity of the processed waste. After this treatment, the waste is then landfilled. This process significantly reduces methane emissions from the landfilled waste, compared with untreated MSW.
4. **Composting:** Composting is mainly used for food and garden wastes, it is an anaerobic method (i.e. requires oxygen from the air) of decomposing organic solid wastes. Compost is used for enriching soil. Use of compost has beneficial effects on greenhouse gas emissions as use of compost replaces other greenhouse gas intensive products such as fertiliser and also leads to storage of carbon in the soil.

5. **Anaerobic digestion (AD):** Anaerobic digestion is a biological process that takes place in sealed vessels in the complete absence of air. The sealed vessels where anaerobic digestion takes place is also know as a digester. Anaerobic digestion process converts organic or biodegradable waste to a biogas that contains Methane and Carbon dioxide, which can be used as a fuel to replace fossil fuels. Waste such as animal manures, food scraps, fats, oils, greases, industrial organic residuals and sewage sludge are processed in a digester to produce biogas. The material that is left after anaerobic digestion takes place is known as "digestate." Digestate is rich in nutrients and can be used as fertilizer for crops. Biogas is a renewable energy source that can be used in variety of ways such as to power engines, produce mechanical power, heat and/or electricity (including combined heat and power systems); fuel boilers and furnaces; heating digesters and other spaces; run alternative-fuel vehicles and supply homes and business through the natural gas pipeline. Application of biogas is mainly dependent on the quality of the biogas. For instance, biogas that is cleaned and treated to meet pipeline quality standards can be distributed through the natural gas pipeline and used in homes and businesses. Biogas can also be cleaned and upgraded to produce compressed natural gas (CNG) or liquefied natural gas (LNG) that can be used to fuel cars and trucks[7].

6. **Recycling:** Recycling is the process of converting waste materials into new materials and objects by reusing the materials contained within the waste material. Recycling saves significant amount of greenhouse gas emissions (GHG), as it reduces energy that results from the extraction, refinement, transportation and processing of raw materials into products. For example, recycling a tonne of aluminium saves 1.3 tonnes of bauxite residues, 15 m3 of cooling water, 0.86 m3 of process water and 37 barrels of oil, while preventing the emission of 2 tonnes of carbon dioxide and 11 kg of sulphur dioxide[8]. Recycling decreases the amount of rubbish sent to landfill and reduces the need for new waste disposal facilities.
7. **Waste prevention:** Waste prevention is considered the most important action in the waste management hierarchy and it is the most environmentally friendly waste management option.

7) USEPA
8) UNEP 2013

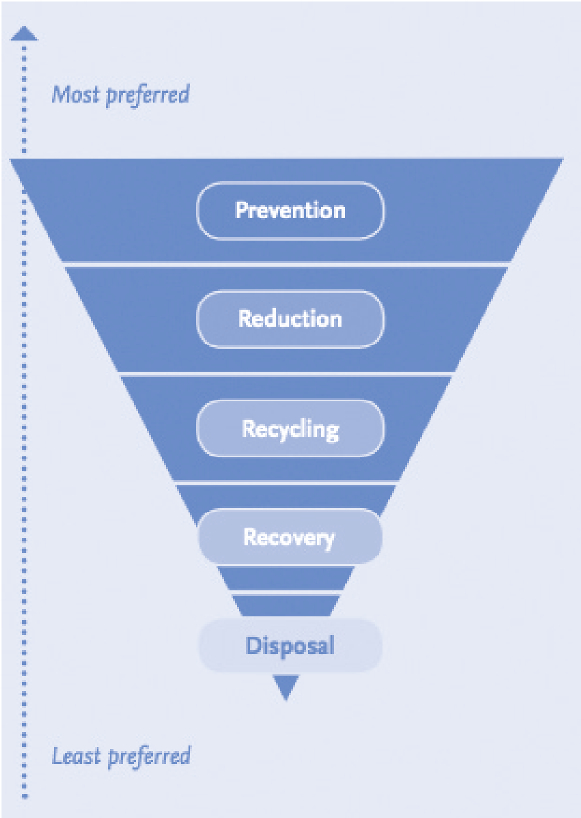


**Figure 4: Waste Management Hierarchy (Source: UNEP 2011)**

Waste prevention nullifies waste related GHG emissions and other negative burden to the environment. It avoids the need to process the waste and plays an important role in decoupling waste generation from economic growth.

# Ⅳ. Climate impacts of prevailing waste management practices

# Ⅳ. Climate impacts of prevailing waste management practices

Methane (CH4) emissions from landfill are the major source of greenhouse gas (GHG) emissions in the waste sector that contributes to global warming and climate change. Methane is a powerful GHG, which has a global warming potential (GWP) 25 times that of Carbon Dioxide (CO2). As discussed in the earlier section of this report, waste contains organic material, such as paper, wood, food and garden clippings etc that starts to decompose once waste is deposited in a landfill. The microbes gradually decompose organic material over time, Methane (CH4) (approximately 50%), Carbon Dioxide (CO2) (approximately 50%), and other trace amounts of gaseous compounds (< 1%) are generated and form landfill gas[9]. It is important to note that the gradual decay of the organic material in a landfill generates emissions even after waste disposal has stopped. This is due to the fact that the chemical and biochemical reactions take a while to progress and merely a small amount of the carbon contained in waste is emitted in the year when the waste is disposed, most of the carbon contained in waste is released gradually over a period of years. It is estimated that decay of organic waste contributes 5% of greenhouse gases globally[10].

9) UNEP 2010
10) UNEP 2013

# Ⅴ. Waste as a valuable source of energy: An opportunity to create energy from waste

# V. Waste as a valuable source of energy: An opportunity to create energy from waste

In general, waste to energy is a broad term that covers any process that converts a waste source into energy such as electricity, heat or transport fuel. There are various types of waste to energy technologies, however, the aim of all waste to energy processes are essentially the same i.e. reduce the volume of waste, consequently reduce the volume requiring disposal in landfill; reduce the biodegradable fraction of waste to zero and produce useful commodities such as electricity or heat from non-recyclable waste. Waste to Energy technology can be split into main three categories: Thermochemical technology, Biochemical technology and Chemical technology as shown in the Figure 5 below.

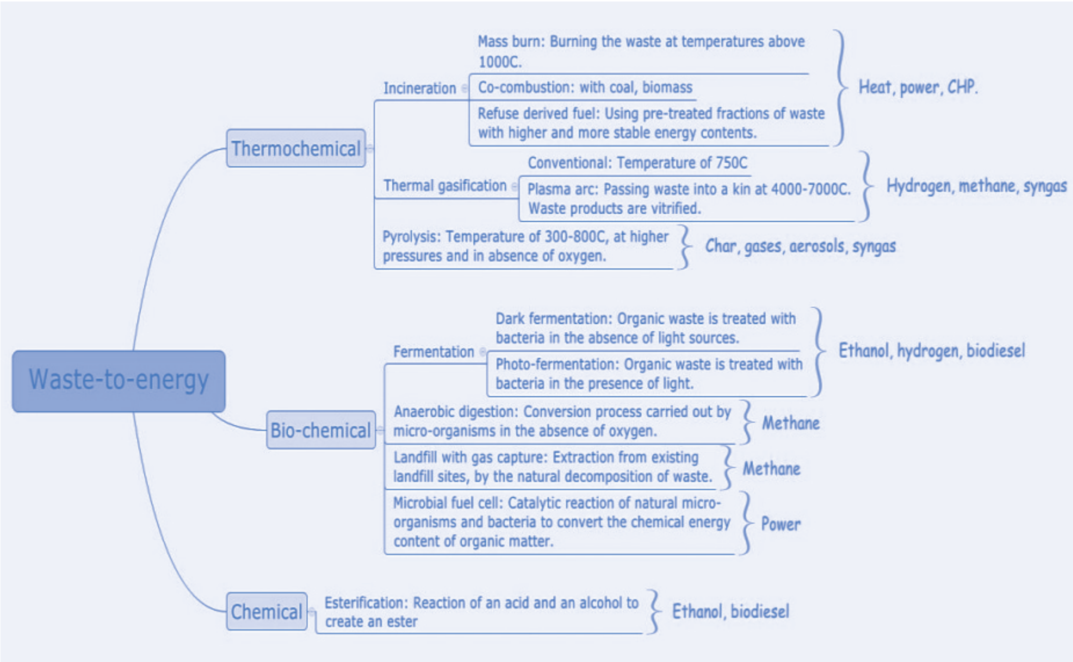


**Figure 5: Waste to Energy Technologies (Source: World Energy Council 2016)**

Incineration technology combust solid waste and convert it to heat and electricity. After the combustion process, superheated steam is produced and then it is used within a cogeneration system to produce electricity and heat. Greenhouse gas emissions and air pollution is considered as a negative environmental impact of waste incineration.

The gasification process breaks down the solid waste or any carbon based waste feedstock into useful byproducts that contain a significant amount of partially oxidized compounds, primarily a mixture of carbon monoxide, hydrogen and carbon dioxide (WEC 2016). The produced gas, which is called syngas, can be used for various applications after syngas cleaning process. Once the syngas gas is cleaned, it can be used to generate high quality fuels, chemicals or synthetic natural gas (SNG); it can be used in a more efficient gas turbines and/or internal combustion engines or it can be burned in a conventional burner that is connected to a boiler and steam turbine[11)].

Pyrolysis is the thermal degradation of solid waste in the absence of oxygen. It is an emerging thermo-chemical waste conversion technology that involves the thermochemical decomposition of solid waste. Pyrolysis process converts waste into gas (syngas), liquid (tar) and solid products (char).

Biochemical technologies utilise microbial processes to transform waste and are limited to biodegradable waste. As stated in the Section 3 of this report, Anaerobic Digestion (AD) is a biochemical process by which organic material is broken down by micro-organisms in the absence of oxygen, producing biogas, a methane-rich gas used as a fuel, and digestate, a source of nutrients used as fertiliser[12)].

In fermentation process organic waste is converted into an acid or alcohol in the absence of oxygen. One of the major products of fermentation process is bio-ethanol, which is used in the transport vehicle fuel. In the landfill with gas capture technology, the methane emitted in landfill gas is captured and utilised as energy source (i.e. heat and/or electricity).

Microbial Fuel Cells are biochemical-catalysed systems in which electricity is produced by oxidising biodegradable organic matters in the presence of either bacteria or enzyme[13)]. This technology is considered to be still in its infancy. The esterification process, which is one of the prominent chemical process technologies, involves the chemical reaction of fat or oils with alcohol in the presence of a chemical catalyst such to produce ethanol and biodiesel.

It can be concluded from the example above that there are significant opportunities to create energy in various forms from waste. There are waste to energy technologies that are matured, at its infancy and under development. One of such technologies -, Anaerobic Digestion (AD) technology is a matured technology with numerous benefits for the local community, farmers and government in both developed and developing countries.  The technology produces biogas which is a renewable energy source that can be used in variety of ways such as to power engines, produce mechanical power, heat and/or electricity; fuel boilers and furnaces; run alternative-fuel vehicles and supply homes and business through the natural gas pipeline. The section below discusses the role of waste to renewable energy projects based on Anaerobic Digestion (AD) technology in achieving SDGs.

11) Arena 2012 as cited in World Energy Council 2016
12) WEC 2016
13) Rahimnejad et al. 2011 as cited in WEC 2016

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# Ⅵ. Role of waste to renewable energy projects in achieving Sustainable Development Goals 2030

# Ⅵ. Role of waste to renewable energy projects in achieving Sustainable Development Goals 2030

The Sustainable Development Goals (SDGs) are targets that needs to be met by 2030, meaning, the governments and businesses around the world has approximately 12 years to take necessary action to achieve this goal. Reliable, clean and affordable energy has the most important role to play in achieving SDGs as energy is essential to sustainable development. There are still 1.1 billion people who do not have access to electricity and approximately 2.9 billion people still rely on wood, coal, charcoal, agriculture residues or animal dung to cook their meals and heat their homes[14)]. Solid fuels and inefficient cooking and heating devices expose households to smoke and fumes causing serious health problems, resulting in more than 4 million premature deaths per annum globally, mostly of women and children[15)]. Therefore, achieving SDG 7 is fundamental to all aspects of development. Access to affordable, sustainable and reliable energy is critical for improving the health and livelihoods of billions of people around the world. With pressure increasing to utilise wastes effectively and sustainably, the production of biogas from waste represents one of the most prominent solutions to achieve SDGs.

Biogas is a renewable energy source, which consists of different gases that are produced by the breakdown of organic matter in the absence of oxygen. This process is known as Anaerobic Digestion (AD). An AD system as shown in Figure 6 below utilizes a digester as an airtight chamber where bio solids, manure, food waste, other organic wastewater streams, or combinations of these feedstock decompose. This process produces biogas (which is a blend of methane and carbon dioxide) and digestate. Anaerobic Digestion (AD) systems vary from small-scale digesters to advanced systems. There are several designs for AD systems that depend upon the feedstock, facility location, and desired outcome.

14) UNDP SDGs
15) WHO, 2016 as cited in UNEP SDG

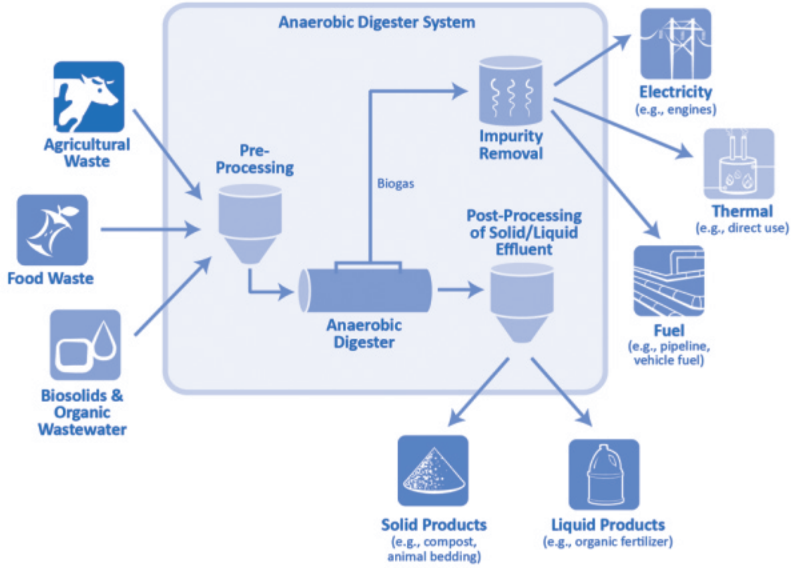


**Figure 6: Anaerobic Digestion Process (Source: Global Methane Initiatives 2013)**

Biogas has various applications; one of the most common uses of biogas is where the biogas is used to produce electricity, heat and steam, it is also used as a vehicle fuel when upgraded to boost its methane content. In developing countries biogas is mainly used for cooking and lighting. Biogas systems also produce nutrient-rich fertilizer that is can be applied to crops, flowers, and trees. Such fertilizer increases agricultural productivity and long-term soil fertility.

Both developed and developing countries have been utilizing various biogas technologies to generate heat, steam and electricity for a number of years. For instance, the total number of biogas plants in Europe in 2013 was 14,572, out of which Germany had the most developed biogas industry having 9,035 plants in operation (i.e. 62% of total number of plants in Europe), followed by Italy (1,391 plants), Switzerland (620 plants) and France (610 plants)[16]. These biogas plants generate biogas from landfill, sewage, agriculture energy crops, agricultural residues and manure, industrial food and beverage and bio waste. For instance, countries like Germany, Italy, Czech Republic and Austria predominantly produces biogas from agricultural feedstock as compared to some European countries that have a slightly mixed share of landfill, sewage sludge and agriculture based biogas plants. France produces biogas mainly from organic waste and on landfills and Switzerland and the United

16) Torrijos 2016

Kingdom extracts biogas mainly from sewage sludge. These countries mainly produce electricity and heat from the biogas and biomethane at certain extent. In 2013, total biogas production in Germany was 65,731 GWh with 24,419 GWh of electricity and 34,762 GWh of thermal energy. It is important to note that, in 2015, renewable energy sector employed 363,100 people in Germany out of which 41,000 jobs were in the biogas sector. Similarly, in Italy, the biogas sector generated 3,670 jobs[17)]. European countries view biogas production in as playing an important role in maintaining rural economies. Some of the most developed of EU countries such as Germany, Sweden and the United Kingdom have sought to create biogas-related jobs[18)]. European Union is a net importer of oil and natural gas, and it considers bio-based fuel as one way to reduce dependency on energy exports and transport fuel price volatility. Biogas production can certainly address the energy security of any oil and gas-importing nation. The United States of America (USA), in 2013, collected landfill-based biogas from 564 out of 2,434 (23%) landfills for electricity generation or direct use[19)].

Biogas in developing countries has been proven to be a valuable energy resource. For instance, in Peru, 14 percent of primary energy consumed is biogas, primarily in rural areas across the country[20)]. Biogas in developing countries addresses two main issues - providing thermal energy for cooking and providing electrical energy to homes that have no access to main electric grid. Biogas has also been used for lighting purposes in some countries; biogas-based lighting benefits communities that are not connected to the main electric grid.

In developing countries, biogas cook stoves are attractive in the places with wood scarcity. These stoves avoid the use wood or charcoal, which often is unsustainably sourced. Biogas in those places is produced from locally available agricultural residues or from animal or human waste and as a bi-product produces valuable organic fertiliser, which is easy to store and transport. Biogas cook stoves have positive environmental performance; emissions otherwise resulting from biogas decay are avoided, thereby reducing the release of pollutants including black carbon, carbon monoxide and methane[21)]. Each year, household air pollution (HAP) is estimated to cause 4 million deaths worldwide[22)]. Biogas stoves reduce household air pollution and associated diseases; the health benefits to women and children are greatest as they are present when cooking takeplace. China leads the world in biogas digester installations for cooking, accounting for over half of all installations globally[23)].

The following section outlines successful case studies of waste to renewable energy projects based on Anaerobic Digestion (AD) biogas technologies in both developed and developing countries and exhibits how these projects help in meeting the SGDs.

17) Torrijos 2016
18) AEBIOM 2009 Cited in Murray et.al. 2014
19) Murray et.al. 2014
20) Global Methane Initiative 2013
21) Grieshop et al, 2011 as cited in IRENA 2017
22) WHO, 2012 as cited in 2017
23) IRENA 2017

## 6.1 Successful cases studies (Developed Country)

### 1) Frogmary anaerobic digestion plant in the UK

This plant processes approximately 43,9000 tonne of agriculture waste and energy crops annually, namely; cattle slurry, chicken manure, cattle manure, maize silage, sugar beet, and grass silage to produce biogas. The plan exports mainly biomethane (2.5 MW) and 15% of the biogas produced in the process is burnt in a Combined Heat and Power (CHP) module, which produces electricity and heat. The electricity produced is fed into the local grid network. The plant also produces fertilizer from the fermentation process residue (digestate) that is being used in the farm. Use of fertilizer improves the sustainability of farming by reducing emissions of greenhouse gases associated with fertiliser manufacture, and by reconnecting nutrient cycles[24].

**Figure 6: Frogmary anaerobic digestion project in the UK (Source: EBA 2018)**

This project has not only generated renewable energy or heat supply, however, have positively addressed the social and environmental issues such as waste reduction, soil improvement, reduced pollution and creation of new jobs. This project is a good example of how waste to renewable energy project plays an important role in achieving SDGs. This project helps achieve following SDGs:

24) Eurpoean Biogas Association (EBA) 2018

| Sustainable Development Goals(SDGs) | Frogmary Waste to Renewable Energy Project |
|---|---|
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | – Produces reliable and sustainable energy; reduces dependency on fossil-fuel-based energy sources<br>– Utilises locally produced wastes and crops to generate energy for rural communities |
| Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | – Demonstrates innovation and sustainability through extraction of energy from local waste and using it for self-consumption |
| Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable | – Prevents spread of diseases through collection and appropriate management of organic waste<br>– Improves urban air quality by substituting fossil fuel with biomethane in vehicles<br>– Reducing greenhouse gas emissions through biogas-based renewable energy |
| Goal 13: Take urgent action to combat climate change and its impacts | – Reduces GHG emissions by replacing fossil-fuel-based energy sources with biogas with digestate biofertiliser<br>– Reduction of methane and nitrous oxide emissions from livestock manure<br>– Reduction of methane and generation of renewable energy from food and other organic wastes |

### 2) Anaerobic Digestion (AD) Plant ZEMKA in Austria

This Anaerobic Digestion plant in Austria utilises food waste, sewage sludge, liquid wastes and bio waste to produce biogas. It treats approximately 18,000 tonnes of waste per year to produce 15 GWh of energy that results into a saving of approx. 3,000 tonnes CO2 per year[25]. The produced biogas is used in heating the neighbouring thermal bath, facilities' own heat demand and residual digestate is further treated in a bio waste composting line to make nutrient-rich digestate fertiliser.

25) EBA 2018

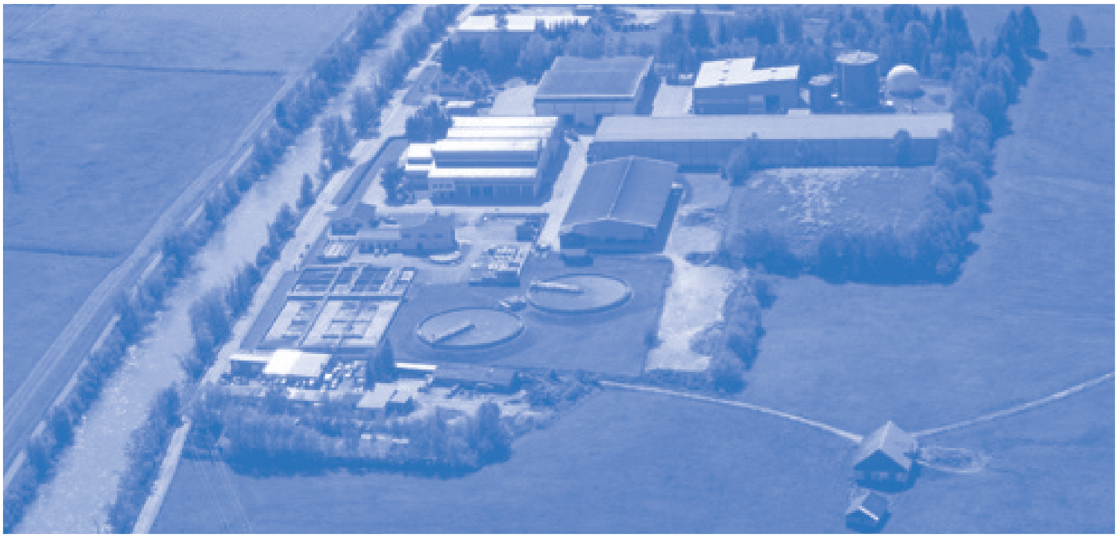

**Figure 7: ZEMKA Project in Austria (Source: EBA 2018)**

Prior to the commissioning of this plant, sewage sludge, kitchen and food waste had to be transported to other Austrian States that had made waste disposal costly for the local resident and industry. This plant is a good example of utilization of municipal waste to create renewable energy, it also addresses key issues at municipal level such as job creation, bolstering local infrastructure. In terms of SDGs, this project meets following goals.

| Sustainable Development Goals (SDGs) | ZEMKA Waste to Renewable Energy Project |
| --- | --- |
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | - Produces reliable and sustainable energy; reduces dependency on fossil-fuel-based energy sources<br>- Utilises local waste to generate energy for rural communities |
| Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | - Demonstrates innovation and sustainability through extraction of energy from local waste and using it for local consumption |
| Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable | - Prevents spread of diseases through collection and appropriate management of organic waste |
| Goal 13: Take urgent action to combat climate change and its impacts | - Reduces GHG emissions by replacing fossil-fuel-based energy sources with biogas with digestate bio fertiliser<br>- Reduction of methane and generation of renewable energy from food and other organic wastes |

## 6.2 Successful cases studies (Developing Country)

### 1) Huimbayoc Project in Peru

This project provides electricity from biogas to an isolated community - Santa Rosillo, in Peru that had no prior access to electricity. Due to the distance, grid connection cost, and number of inhabitants, this community was not considered for grid connection. The project utilises animal manure to generate 8.74 to 11.65 cubic meters of biogas a day, which provides 16kW of power[26]. The slurry is used as fertilizer to increase yields of crops. Prior to this project, the manure built up in the village had no productive use or disposal pathway.

**Figure 8: Huimbayoc Project in Peru[27]**

This project is a successful example of waste to renewable electricity generation, which has improved the community access to energy. Communal centre, school, clinic, and church as well as public lighting for evening activities use the electricity produced by the project. The installation of public lighting from the electricity generated has made it possible for local residents to engage in productive activities after dark. In terms of SDGs, this project meets following goals.

26) Global Methane Initiatives 2013

27) Photo Source: GMI 2013 & Biocycle https://www.biocycle.net/2014/02/21/cooperative-approaches-to-international-agricultural-biogas-projects/

| Sustainable Development Goals (SDGs) | Huimbayoc Waste to Renewable Energy Project |
|---|---|
| Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture | - Use of nutrient-rich digestate fertiliser increases crop yields<br>- Soil restoration through the recycling of nutrients, organic matter, and carbon |
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | - Produces reliable and sustainable energy; reduces dependency on fossil-fuel-based energy sources<br>- Utilises local biomass waste to generate electricity for rural and remote communities |
| Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | - Encourages growth of community based enterprises by providing reliable electricity<br>- Generates short-term construction employment and long-term plant management and maintenance employment |
| Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable | - Prevents spread of diseases through collection and appropriate management of organic waste |
| Goal 13: Take urgent action to combat climate change and its impacts | - Reduces methane and nitrous oxide emissions from livestock manures<br>- Reduces GHG emissions by replacing fossil-fuel-based energy sources with biogas with digestate bio fertiliser |

### 2) Kolar Biogas Project, India

This biogas project in Karnataka state of India has installed domestic biogas plants at 10,000 rural households. The biogas installations are fed with animal dung and kitchen wastewater where the generated gas is then used for cooking purposes and the slurry of the remaining manure is used as fertilizer. Prior to the installation of domestic biogas plant, firewood and kerosene were for cooking, which had led to a degradation of the forest cover in project region. Women and children had to spent significant amount of time (upto 4 hours a day) to collect the firewood for cooking.


**Figure 8: Kolar Biogas Project in Karnataka, India (Source: myclimate 2012)**

This project has positively contributed in easing the workload for women and children and lessening health problems caused by indoor pollution. By reducing the time needed for collecting firewood and cooking, more time is devoted by the householders for other income generation activities and studying.

The biogas produced from cattle manure is a renewable source of energy. The project saves greenhouse gas (GHG) emissions as it displaces GHG emissions from kerosene and fuel wood that the householders were using for cooking prior to the project. The project avoids GHG emissions that were emitted from decay of cattle manure. In terms of SDGs, this project meets following goals

| Sustainable Development Goals (SDGs) | Kolar Waste to Renewable Energy Project |
|---|---|
| Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture | - Restores soils through the recycling of nutrients, organic matter, and carbon<br>- Increases crop yields through use of bio fertilizer |
| Goal 3: Ensure healthy lives and promote well-being for all at all ages | - Reduces indoor air pollution by substituting fossil fuel and firewood with biogas<br>- Utilises organic wastes to reduce odours and spread of diseases |
| Goal 5: Achieve gender equality and empower all women and girls | - Reduces the burden of collecting firewood and improves the quality of life (mainly for women and children) |
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | - Reduces dependence on fossil-fuel-based energy sources<br>- Produces reliable and sustainable energy |

| Sustainable Development Goals (SDGs) | Kolar Waste to Renewable Energy Project |
|---|---|
| Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all | - Improves the economic level of the rural community by providing employment opportunities during the construction phase, and operation phase (maintenance, training etc). |
| Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable | - Prevents spread of diseases through collection and appropriate management of organic waste<br>- Improving air quality by substituting fossil fuel and firewood for domestic cooking |
| Goal 13: Take urgent action to combat climate change and its impacts | - Reduces deforestation by replacing firewood with biogas<br>- Reduces methane and nitrous oxide emissions from livestock manures<br>- Reduces GHG emissions by replacing fossil-fuel-based energy sources with biogas and bio-fertiliser |
| Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss | - Recirculates nutrients and organic matter in the soil in the form of bio-fertiliser<br>- Replaces firewood with biogas that reduces deforestation; slowing deforestation yields direct benefits like slowing soil erosion, destruction of natural habitat and loss of biodiversity |

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# Ⅶ. Conclusion

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Waste is an unavoidable product of our society; waste volumes are increasing rapidly, even faster than the rate of urbanization both in developed and developing countries. Waste has an adverse impact on human health and the environment. Methane emissions pertinent to the waste contributes in global warming and climate change. Therefore, one of the greatest challenges of the future generation is to manage the large quantities of waste in a way that will not have any negative impact on the environment and the climate. There are several waste to energy technologies that convert waste into useful energy forms, out of which Anaerobic Digestion (AD) can play an important role in meeting several SDGs (that needs to be met by 2030) at a much rapid rate. Some of the key benefits of Anaerobic Digestion of organic waste that help to meet SDGs includes generation of renewable energy (SDG 7); reduction of greenhouse gas emissions (SDG 13); reduced dependency on fossil fuels (SDG 13 and SDG 11); job creation (SDG 8); soil restoration through the recycling of nutrients (SDG 2), increased crop yield (SDG 2), achieve gender equality and empower all women and girls (SDG 5) and reduce deforestation (SDG 15).

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