BACOPO ENVIRONMENTAL SOLUTIONS INC.

WASTE TO ENERGY

CARIBBEAN TRANSITIONAL ENERGY CONFERENCE

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WASTE TO ENERGY

Waste Management Hierarchy

Energy recovery from the combustion of municipal solid waste (MSW) is a key part of the non-hazardous waste management hierarchy which ranks various management strategies from most to least environmentally preferred. Energy recovery ranks below source reduction and recycling/reuse but above treatment and disposal. Confined and controlled burning, known as combustion, can not only decrease the volume of solid waste destined for landfills, but can also recover energy from the waste burning process. This generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills.

Waste is an inevitable product of society, and one of the greatest challenges for future generations is to understand how to manage large quantities of waste in a sustainable way. One approach has been to minimize the amount of waste produced, and to recycle larger fractions of waste materials. However, there still is a considerable part of undesired end products that must be taken care of, and a more suitable solution than simple landfilling needs to be found.

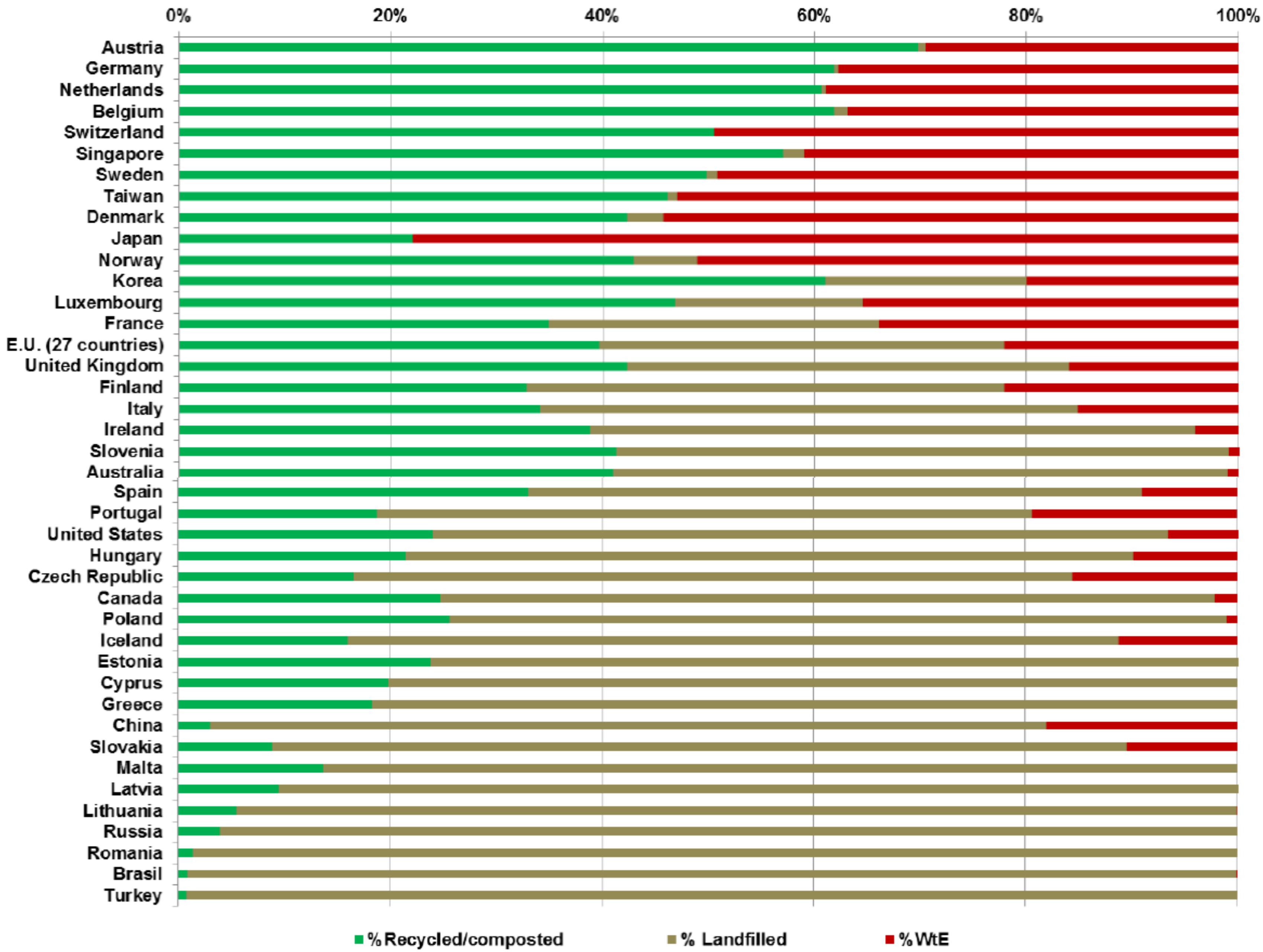
Waste Management Hierarchy

- Prevention (Most Favoured)
- Minimization
- Reuse
- Recycling
- Energy Recovery
- Disposal (least Favoured)

Global Perspective on Waste to Energy (WTE)

The incineration of waste for energy recovery is an important component of the waste management strategies of many countries. There are more than 600 MSW combustion facilities throughout the world that combust about 118 million tonnes of MSW each year. MSW combustion is more prevalent in countries such as Japan, Sweden, Denmark, France and Switzerland, where landfill space is limited.

https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/intl.html


0%
20%
40%
60%
80%
100%
Austria
Germany
Netherlands
Belgium
Switzerland
Singapore
Sweden
Taiwan
Denmark
Japan
Norway
Korea
Luxembourg
France
E.U. (27 countries)
United Kingdom
Finland
Italy
Ireland
Slovenia
Australia
Spain
Portugal
United States
Hungary
Czech Republic
Canada
Poland
Iceland
Estonia
Cyprus
Greece
China
Slovakia
Malta
Latvia
Lithuania
Russia
Romania
Brasil
Turkey
% Recycled/composted
% Landfilled
% WtE

The Figure below produced by the Global WTERT Council shows how jurisdictions around the world manage their solid waste.

Source: Global WTERT Council http://energyrecoverycouncil.org/wp-content/uploads/2016/06/ERC-2016-directory.pdf

Europe is the largest and most sophisticated market for WTE technologies, accounting for 47.6% of total market revenue in 2013. The Asia-Pacific market is dominated by Japan, which uses the majority of its solid waste for incineration and is the number 1 user of WTE in the world. However, the fastest market growth has been witnessed in China, which has more than doubled its WTE capacity in the period 2011-2015. China built sixty WTE plants in 2012-2014 and has become the No.2 user of WTE in the world. The U.S. is the number 3 user.

https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf

Bermuda has 1 incinerator that is processing ~ 70,000 tonnes/year. The construction of the facility began in 1991, and operations started in late 1994. The cost of the facility was $US70 million and was financed by the Government of Bermuda. The calorific value of the waste received in the facility is in the range of 9 to 11 MJ/kg and the facility produces, on average, around 18,000 MWh of electricity per year. Ferrous metals are removed from the bottom ash with a magnetic separator, and the remaining ash is mixed with concrete to form two-ton, $1m^3$ concrete blocks that are used for shore protection and land reclamation at the Bermuda airport.

https://www.gov.bm/garbage-and-recycling

http://www.seas.columbia.edu/earth/wtert/sofos/Rodriguez_thesis.pdf

WTE in the Caribbean

Cuba

At a conference on energy recovery held in September, 2017 one of the topics discussed was *Advancing Sustainable Waste and Biomass to Energy in Cuba.* The conclusion of the moderator leading the discussion on this topic was the following. "A huge potential exists to develop waste-to-energy and biomass-to-energy projects, attracting worldwide investors in this infant Caribbean market."

https://swana.org/Events/WASTECON/ConferenceProgram/2017/AdvancingSustainableWasteandBiomasstoEnergyinCuba.aspx

Haiti

Haiti is developing a waste management facility. The facility will receive truckloads of mixed municipal waste which will be separated into organic material and non-organic materials like metals and plastics. The non-organic material will be sorted, baled and used domestically as well as sold on the international recycling market. The remaining organic fraction will be processed in an anaerobic bio digester which will produce bio fertilizer and biogas.

https://renewableenergycaribbean.com/2018/02/20/waste-to-energy-plant-under-construction-in-haiti/

Dominican Republic

The National Energy Commission in the Dominican Republic granted Streamline Integrated Energy a provisional concession for the 50MW SPM-Planta Basura Energía project about 1 year ago. The plant will use solid urban waste and take advantage of the country's renewable energy incentives law. Streamline was given 18 months to complete survey work, analysis and studies in the lead up to a definitive decision to proceed with the development.

https://www.bnamericas.com/en/news/electricpower/waste-to-energy-developer-eyes-dominican-republic/

Puerto Rico

Energy Answers, the company behind a proposed WTE incinerator in Puerto Rico, has been trying to get the project rolling since 2010. The company had struggled to find funding for the incinerator, but earlier this year, it took advantage of a fiscal bill meant to help push through critical energy projects in the wake of the disaster left behind by Hurricane Maria. Public opposition is stalling the project.

https://earther.gizmodo.com/puerto-rican-city-tells-trash-burning-power-plant-to-fu-1825775311

Jamaica

As of 14 months ago, Jamaica was considering WTE. According to the broad responsibilities of the Jamaican waste management department, it is "operating solid waste disposal sites in the medium term while preparing them for divestment to the private sector."

http://www.nswma.gov.jm/aboutus.php

Trinidad and Tobago

A technical and policy support review to develop a sustainable energy program for Trinidad and Tobago was completed in 2014. A waste characterization study and analysis of WTE was recommended. It appears that nothing has been done to advance WTE.

https://www.nist.gov/sites/default/files/documents/iaao/MaryRose.pdf

Guadeloupe

A firm from Belgium was to construct a WTE plant in Guadeloupe in 2011 to manage 130,000 tonnes/year. The plant was never built.

https://waste-management-world.com/a/new-wte-plant-in-guadeloupe

Martinique

Martinique has a WTE facility in Fort-de-France that started operations in 2002. It has a capacity of 112,000 tonnes/year. The calorific value of the waste received in the facility is between 4.2 and 8.4 MJ/kg, and generates between 40,000 and 45,000 MWh/year of electricity. The owner of the facility is UIOM Fort-de-France and the shareholders are Veolia Environment SA.

http://www.seas.columbia.edu/earth/wtert/sofos/Rodriguez_thesis.pdf

https://www.industryabout.com/country-territories-3/2222-martinique/waste-to-energy/34780-fort-de-france-incineration-plant

Bahamas

Stellar Energy has been trying to advance the development of a plasma arc gasification plant in the Bahamas for 7 years.

https://waste-management-world.com/a/stellar-energy-defends-plasma-gasification-waste-to-energy-plan-for-bahamas

Barbados

Barbados had a plan to build a plasma arc gasification plant for a proposed $700 million but the plan was abandoned due to public opposition. As of 1 year ago, debate is continuing in the Barbados Senate to revisit the development of WTE.

https://barbadostoday.bb/2017/08/03/we-need-to-get-back-to-waste-to-energy-worrell/

Saint Lucia

The Saint Lucia Solid Waste Management Authority, through funding assistance from the United Nations Environment Program, is seeking to develop a strategy for solid waste management. A consultant has been contracted to undertake the development of the strategy which will serve to guide the work of the SLSWMA during the next ten years.

http://sluswma.org/unep-funds-solid-waste-management-strategy-for-saint-lucia/

Curacao

Curacao's National Energy Policy states the following:
Waste has an energetic value. Therefore, electricity can be produced by waste combustion. Apart from reducing the need for space for landfills, it helps to become less dependent on imported fuels. The National Energy Policy aims to resolve the solid waste problem by installing a 7−15 MW WTE facility by 2021, taking into account environmental concerns. Presently, there is no WTE facility on

Curaçao. The landfill will be full in 10 to 15 years and other solutions are needed for waste disposal. WTE conversion provides a solution for the waste management problems. It will also contribute to a more sustainable electricity supply. When investing in a WTE facility, solely proven technology will be considered. The investment, construction and operation of the facility will be done by an independent party, buying waste from waste management company Selikor and selling electricity (and possible water) to the utility Aqualectra. The optimal size of the facility will be established after an assessment of all recycling options.

https://www.btnp.org/files/Publicaties_Overige_beelden/NATIONAL_ENERGY_POLICY_for_CURACAO.pdf

Aruba

Aruba released a Request for Information in February, 2018 for sustainable waste management.

http://newenergyevents.com/aruba-releases-rfi-for-sustainable-waste-management/

United States Virgin Islands

A technical report produced by the National Renewable Energy Laboratory of the US Department of Energy concluded the following: "A general finding of this evaluation is that WTE operations, if implemented appropriately, serve a beneficial role in an integrated solid waste management program for a community. The appropriateness of WTE for a community must be evaluated on a case-by-case basis and should only be considered after waste reduction and responsible recycling programs are implemented. Specific to the US Virgin Islands, the proposed WTE facility appears to:

• Have economics similar to WTE facilities in the continental United States in terms of waste disposal fees and overall life-cycle costs to the community (higher costs in the US Virgin Islands are expected due to lack of economies of scale).

• Offer a lower life-cycle impact on the environment (in terms of energy consumption and net greenhouse gas emissions).

• Have the potential to meet all EPA emissions standards (based on similar WTE plants in the United States)."

Responding to calls for the construction of a waste energy facility in the US Virgin Islands, Governor Mapp said: "I restate my full opposition to waste energy facilities in the Virgin Islands. I have challenged everyone that has come before me … to identify … a plant that exists anywhere on U.S. soil that has been permitted by the (Environmental Protection Agency) EPA for waste energy." He stressed such a facility would require significantly more tonnage of waste than what is produced in the Virgin Islands.

https://www.energy.gov/sites/prod/files/2013/11/f5/waste-to-energy_eval_usvi_nrel_52308_final.pdf

https://stjohnsource.com/2017/11/12/governor-mapp-is-wrong-waste-to-energy-system-can-be-implemented-here/

Grenada

Grenada is reviewing its Waste Management Strategy since it is running out of landfill capacity. It will look at the option of WTE but a senior public relations officer for the Grenada Solid Waste Management Authority said "We ought to think of the cost factors involved."

http://www.nowgrenada.com/2017/11/the-grenada-solid-waste-management-authority-looks-at-waste-management-strategy/

Antigua and Barbuda

In a workshop sponsored by the United Nations Development Programme to review and assist Antigua with its waste management challenge, a statement was made by Antigua that it has committed to a WTE plant by 2025.

http://www.sustainablesids.org/wp-content/uploads/2017/10/Guest-Blogger-Mrs-Ruth-Spencer-on-Waste-Management-in-Antigua-Barbuda.pdf

Saint Kitts and Nevis

The General Manager of the Solid Waste Management Corporation in St. Kitts acknowledges that the island is running out of landfill capacity and that a WTE option needs to be discussed. He pointed out that while this may be a good solution to the current problem, there are several factors that will impact the decision making process. One is the possibility of geothermal energy being chosen over waste to energy and the second is cost.

At the time of the Caribbean Waste Management Conference *SIDS Approaches to Waste Management And The Circular Economy* in Kingston, Jamaica on July 4-6, 2017, Nevis was actively pursuing a WTE system.

https://www.stkittsswmc.com/swmc-addresses-rotary-club-on-the-state-of-waste-disposal-in-st-kitts/

http://www.cep.unep.org/Waste%20Management%20Conference%202017%20Summary.pdf

Sint Maarten

The construction of WTE has long been considered a solution for the landfill problems in Sint Maarten. The latest plan would have the WTE plant charge the local power company 0.26 guilders/kw while the local power company produces power at 0.22 guilders/kw. The local power company would have to pass the increase in price unto its customers and under a worst case scenario this would increase the monthly electricity bill by 60 guilders or ~ US$33.9.

https://stmaartennews.com/opinions/question-nobody-ever-asked/

Saint Barthelemy

Saint Barthelemy is part of the French West Indies. A WTE facility began operation in 2001 with an annual capacity of 7,500 tonnes per year. The Facility is owned by Ounalao Environnement SA and the shareholders are the EDF Group. The process used by the WTE facility is combustion with energy recovery. The amount of steam delivered allows the production of 1,200 - 1,720 m3 of drinking water per day.

http://www.seas.columbia.edu/earth/wtert/sofos/Rodriguez_thesis.pdf

https://www.industryabout.com/country-territories-3/2212-guadeloupe/waste-to-energy/34724-saint-barthelemy-incineration-plant

Montserrat

The Montserrat National Energy Policy 2016-2030 states that Montserrat will "conduct feasibility studies on the use of organic waste, agricultural residues, liquid effluents and municipal waste for power generation."

https://www.scribd.com/document/312298115/The-Montserrat-National-Energy-Policy-2016-2030

Types of WTE Technologies

Treating residual waste with various WTE technologies is a viable option for disposal of WSW and energy generation. There are many factors that will influence the choice of technology and every region will have to properly assess its specific context to implement the most reasonable solution.

Thermo-chemical conversion technologies are used to recover energy from MSW by using or involving high temperatures. They include combustion or incineration, gasification and pyrolysis. *

Combustion

Combustion of MSW is the complete oxidation of the combustible materials contained in the solid waste fuel. Initially, the heat in the combustion chamber evaporates the moisture contained in the solid waste and volatilizes the solid waste components. The resulting gases are then ignited in the presence of combustion air to begin the actual combustion process. The process leads to the conversion of waste fuel into flue gas, ash and heat. The heat released is used to produce a high-pressure superheated steam from water, which is sent either to the steam turbine that is coupled with a generator to produce electricity, or used to provide process steam.

The amount of ash generated ranges from 15-25 percent (by weight) and from 5-15 percent (by volume) of the MSW processed. Generally, MSW combustion residues consist of two types of material: fly ash and bottom ash. Fly ash refers to the fine particles that are removed from the flue gas and includes residues from other air pollution control devices, such as scrubbers. Fly ash typically amounts to 10-20 percent by weight of the total ash. The rest of the MSW combustion ash is called bottom ash (80-90 percent by weight). The main chemical components of bottom ash are silica (sand and quartz), calcium, iron oxide, and aluminum oxide. The chemical composition of the ash varies depending on the original MSW feedstock and the combustion process. Depending on the bottom ash treatment options, ferrous and non-ferrous metals can also be recovered and the remaining ash can be further processed and utilized as aggregate replacement in base road construction, bulk fill, concrete block manufacture, concrete grouting or sent to landfill, where it is often used as cover.

The waste used to fuel the mass burn facility may or may not be sorted before it enters the combustion chamber. Many municipalities separate the waste on the front end to save recyclable products. Mass burn units burn MSW in a single combustion chamber under conditions of excess air. In combustion systems, excess air promotes mixing and turbulence to ensure that air can reach all parts of the waste. This is necessary because of the inconsistent nature of solid waste. Most mass-burn facilities burn MSW on a sloping, moving grate that vibrates or otherwise moves to agitate the waste and mix it with air. Modular Systems burn unprocessed, mixed MSW. They differ from mass burn facilities in that they are much smaller and are portable. They can be moved from site to site. Refuse derived fuel systems use mechanical methods to shred incoming MSW, separate out non-combustible materials, and produce a combustible mixture that is suitable as a fuel in a dedicated furnace or as a supplemental fuel in a conventional boiler system. **

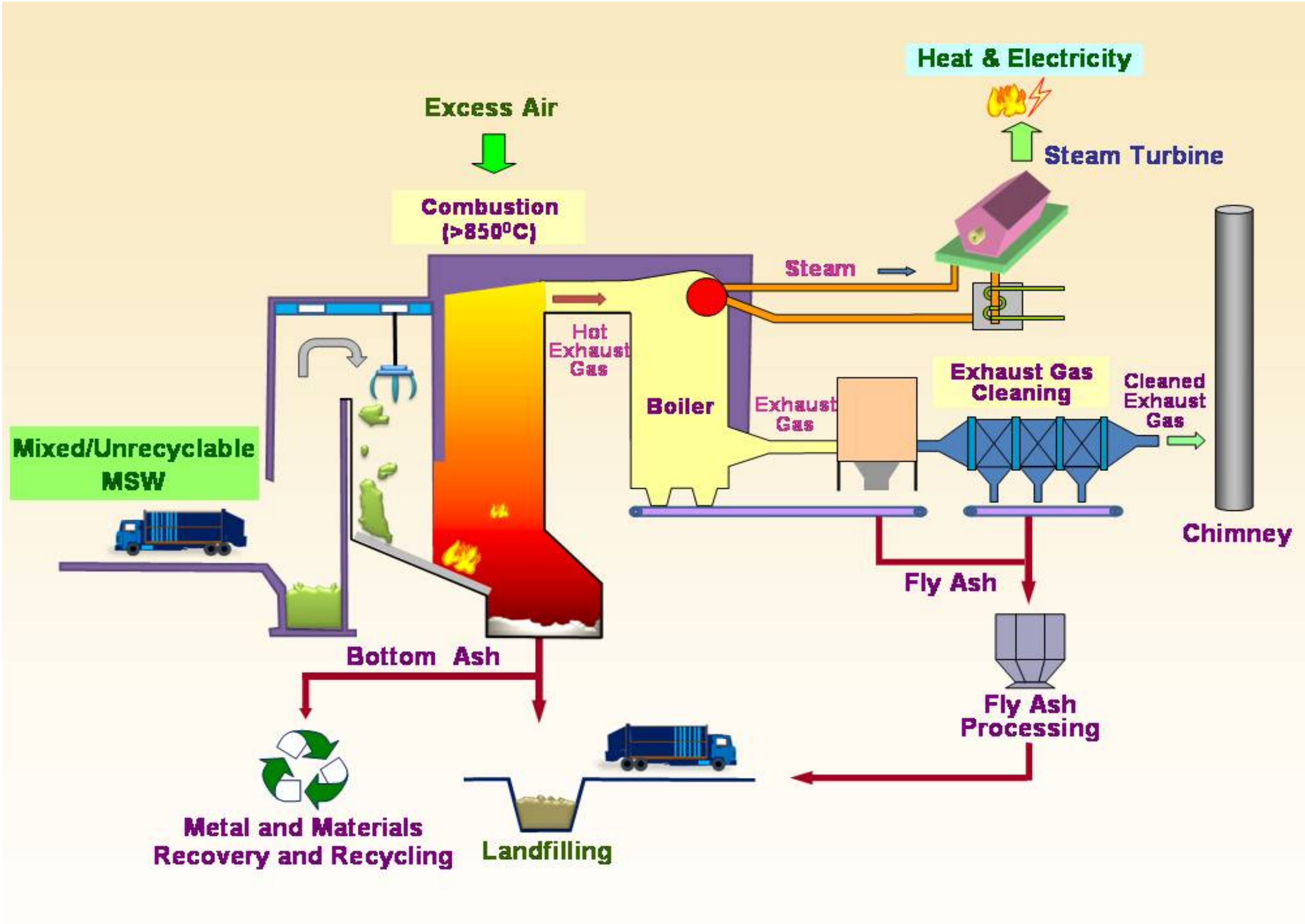
Gasification

Solid waste gasification is the partial oxidation of waste fuel in the presence of an oxidant of lower amount than that required for combustion. 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. Furthermore, the heat required for the gasification process is provided either by partial combustion to gasify the rest or heat energy is provided by using an external heat supply. The produced gas, which is called syngas, can be used for various applications after the syngas cleaning process, which is the greatest challenge to commercialize this plant in large scale. Once the syngas gas is cleaned, it can be used to generate high value commercial products such as transportation fuels, chemicals, and fertilizers; 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. Gasification plants are most successful when fired using a consistent quality fuel. However, the heterogeneous nature of the solid waste fuel makes the gasification process very difficult together with the challenges of syngas cleaning, and there are not many largescale stand-alone waste gasification plants. A manner in which to increase the viability of waste gasification is the improvement of waste sorting and pre-treatment methods. Preparation of a homogenous refuse derived fuel remains one of the most difficult tasks in thermochemical conversion of solid waste. It involves a large amount of mechanical processing and close supervision, which greatly impact operating costs and can account for as much as 40% of the total plant capital costs. If shredding and sorting of the waste can be made simpler and more effective, gasification would become even more advantageous. Similarly, waste gasification will be most successful in communities where there is good recycling practice. A better job of recycling glass and food wastes by city residents will improve the gasification reactions. ***

There are more than 272 operating gasification plants worldwide with 686 gasifiers. See the graph below that is entitled *Number of Gasifiers by Primary Feedstock*. Coal is now the dominant feedstock and will continue to be so for the foreseeable future. There are still gasification plants using oil as a feedstock, but that number has dropped considerably as the price of crude oil has increased. Biomass and waste feed is currently very small. ****

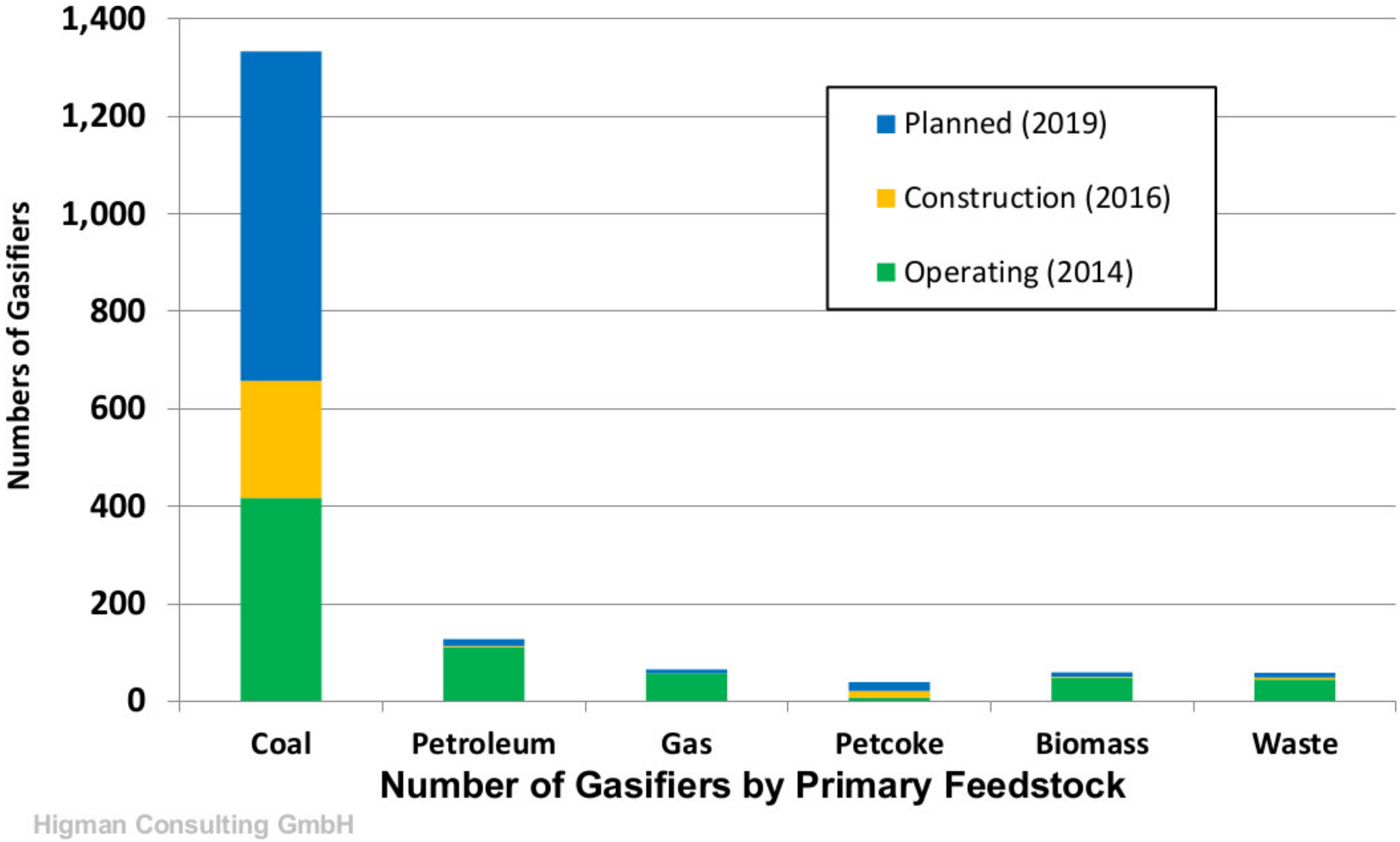
Pyrolysis

Pyrolysis of solid waste fuel is defined as a thermo-chemical decomposition of waste fuel at elevated temperatures, approximately between 500^{o} C and 800^{o} C, in the absence of air and it converts MSW into gas (syngas), liquid (tar) and solid products (char). The main goal of pyrolysis is to increase thermal decomposition of solid waste to gases and condensed phases. The amount of useful products from the pyrolysis process (CO, H2, CH4 and other hydrocarbons) and their proportion depends entirely on the pyrolysis temperature and the rate of heating. It is important to note that the mechanical treatment ahead of gasification, sensitivity to feedstock properties, low heating value of waste fuel, costly flue gas clean-up systems, difficulty of syngas clean-up and poor performance at small scale have been a great challenge during gasification of MSW.



Typical Combustion Flow Chart

Source:https://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/WFdev_IWMFtech.html



Source: https://www.globalsyngas.org/resources/the-gasification-industry/

* https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf

** https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

*** https://www.researchgate.net/publication/285295261_Gasification_of_municipal_solid_wastes
**** https://www.globalsyngas.org/resources/the-gasification-industry/

Energy Production

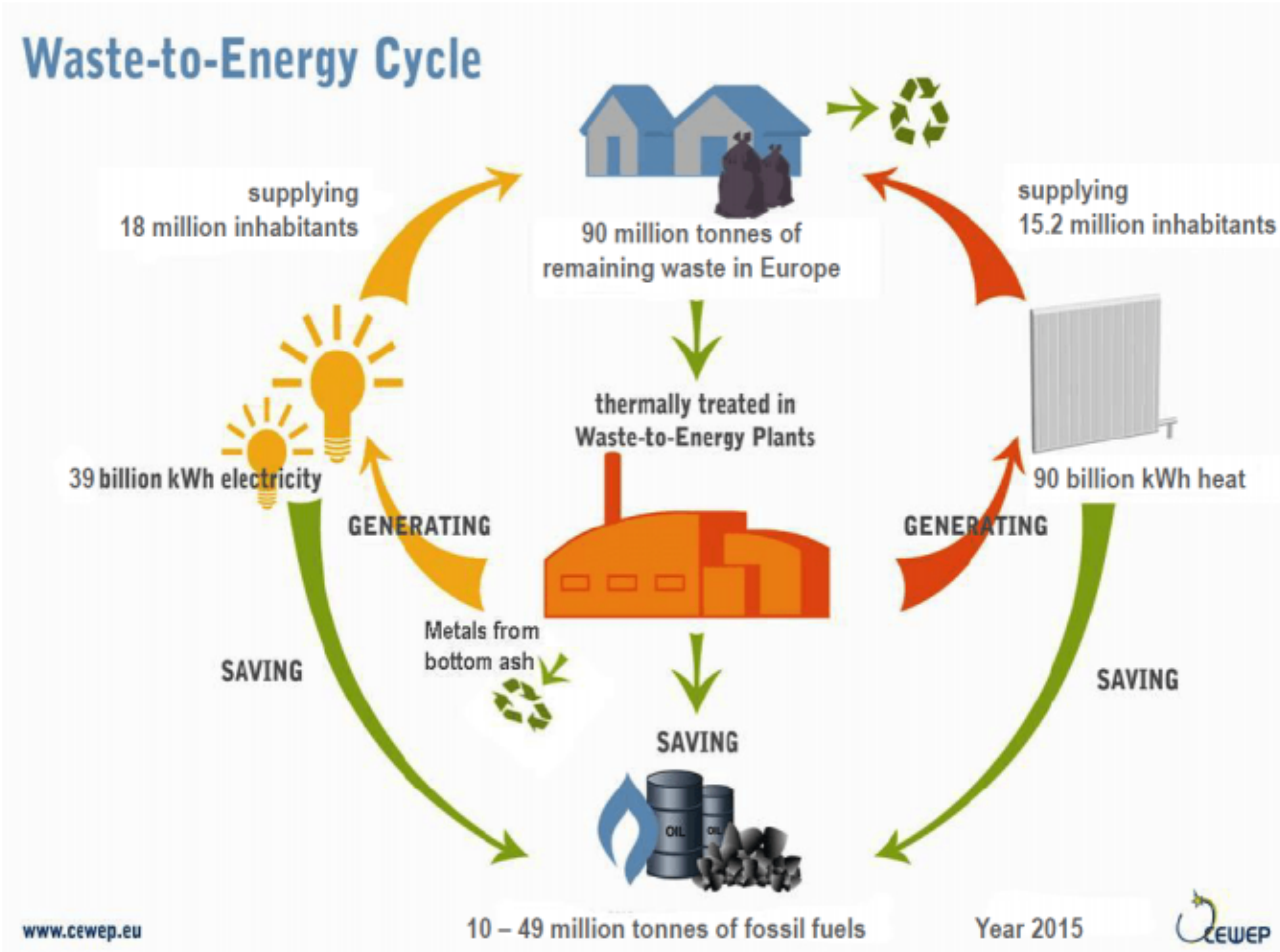
Electricity can be produced from MSW through direct combustion, and the released heat is utilized to produce steam to drive a turbine. This indirect generation has an efficiency level of about 15% to 27%, with modern plants reaching the higher end of the range. The electrical efficiency rate from incineration is usually higher than from gasification due to lower operating temperatures, steam pressure and overall energy required to run the plant. The amount of net energy produced depends on the type of WTE technology used and the composition of the MSW feedstock. Listed below are a number of energy production values from different sources. It appears that the range of net energy produced from the combustion of one tonne of MSW ranges between 500 and 605 kwh.

605 kilowatt hours (kwh) per the combustion of one tonne of MSW *

530 kwh per the combustion of one tonne of MSW **

500-550 kwh per the combustion of one tonne of MSW ***

533 kwh per the combustion of one tonne of MSW (heat was coproduced for this example so ~100 kwh of energy was added to the electrical production number [433 kwh] to account for the electrical energy required to produce heat). WTE plants in Europe can supply 18 million inhabitants with electricity and 15.2 million inhabitants with heat. This is based on 90 million tonnes of household and similar waste that was treated in Europe in 2015. See the Waste-to-Energy Cycle shown in the figure below. ****



* https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw#01

** http://energyrecoverycouncil.org/wp-content/uploads/2016/06/ERC-2016-directory.pdf

*** https://www.quora.com/How-much-electrical-energy-can-be-produced-from-1-ton-of-municipal-waste

**** http://www.cewep.eu/2017/07/02/waste-to-energy-cycle/

Municipal Solid Waste Generation

A study conducted by the World Bank included a table shown below which includes the waste generation per capita, for different regions of the world.

Region	Total Urban Population (millions)	Total Urban MSW Generation (Tonnes/ day)	2012 Urban MSW Generation per Capita (kg/day)	2025 Projected Urban MSW Generation per Capita (kg/day)
Africa	261	169,119	0.65	0.85
East Asia and Pacific	777	738,958	0.95	1.5
Eastern & Central Asia	227	254,389	1.1	1.5
Latin America & Caribbean	400	437,545	1.1	1.6
Middle East & North Africa	162	173,545	1.1	1.43
OECD*	729	1,566,286	2.2	2.1
South Asia	426	192,410	0.45	0.77
Cayman Islands **	~0.059	~59	~1.0	

Total	**2,982**	**3,532,255**	**1.2**	**1.4*** **

Source: https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387- 1334852610766/What_a_Waste2012_Final.pdf

* The OECD is a forum of 34 industrialized countries that develops and promotes economic and social policies. The 34 OECD member countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.
** http://ministryofhealth.gov.ky/sites/default/files/National%20Solid%20Waste%20Management%20Strategy%20Report.pdf

*** Based on projections for population growth and a per capita generation rate of 1.4 kg/day, it is estimated that global waste generation will double by 2025 to over 6 million tonnes of waste per day. It is estimated that by 2100, global waste generation may hit 11 million tonnes per day.

Composition of MSW

The major fractions of solid waste include paper, organic material, plastics, glass and metal. The table below illustrates the composition of solid waste worldwide. As can be seen, nearly half of the produced waste from society is organic. Specific waste products deriving from construction, industrial and commercial waste are not specified in this table, but in some cases can represent the majority of a region's waste production.

Waste Component	% of Total Global Waste Stream*
Organic	**46**
Other	**18**

Paper	**17**
Plastic	**10**
Glass	**5**
Metal	**4**

Source:*https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf

Approximate Net Calorific Value of Common MSW Components

Component	Net Calorific Value* (MJ/kg)
Plastics	**35**
Textiles	**19**
Paper	**16**
Other Materials	**11**
Organic Matter	**4**
Glass	**0**

Metal	**0**

* Generally in order for the combustion process to be self-sustaining, the net caloric value of the incoming waste stream for WTE incineration should be at least 7 MJ/kg.

Source: https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf

Waste Diversion Rate vs. Incineration Rate

A common argument made by those that are anti WTE is that incineration negatively impacts diversion, yet nine (shown in red type below) out of the top eleven countries with the highest MSW incineration rate are on the list of top eleven countries with the highest waste diversion rate. The table below shows the percentage of waste that is diverted, incinerated and landfilled for a number of countries.

Top Eleven Countries with the Highest Waste Diversion	Top Eleven Countries with the Highest Incineration Rate
Korea	Japan
Austria	Denmark

Netherlands	Netherlands
Germany	Germany
Belgium	Belgium
Singapore	Singapore
Switzerland	Switzerland
Norway	Norway
Sweden	Sweden
Luxembourg	Luxembourg
Taiwan	Taiwan

There are also concerns that adoption of WTE treatment encourage production of waste, discourage recycling and are not compatible with the policies that promote a 'zero-waste' economy. In contrast, the countries that recover energy from waste also have high recycling rates, so there is no real basis for this claim.

Emission Standards For WTE Facilities

WTE facilities are subject to standards that are among the most stringent in the world. Under the Clean Air Act, more than $1 billion were invested in upgrades to air quality control systems at America's WTE facilities. The results were so dramatic that the U.S. Environmental Protection Agency (EPA) wrote that the "upgrading of the emissions control systems of large combustors to exceed the requirements of the Clean Air Act Section 129 standards is an impressive accomplishment." In addition to combustion controls, WTE facilities employ sophisticated air quality control equipment, such as selective non-catalytic reduction scrubbers, activated carbon injection, and fabric filter baghouses. As a result of the controls employed at these plants, dramatic reductions in emissions have been achieved, leading EPA to conclude that the emissions performance of waste-to-energy "has been outstanding."*

Waste incinerators have been highly scrutinized by public health agencies, NGO activists and the general public, which influenced the legislators to impose stricter limits on emissions. Government regulators assure the general public that MSW incinerators do not endanger public health safety because it is being warranted that they adhere to the prescribed safety standards.

Criticisms of waste combustion also relate to the actual effectiveness of modern emissions abatement procedures and the inconsistency of monitoring plant operation to the highest standards. Modern plants are equipped with air emissions control technologies that can effectively remove the substances of concern. The best air pollution control system includes dry scrubbing that neutralizes acids followed by a baghouse that filters emissions of metals and organic compounds. These technologies are useful as long as the combustion plants are properly operated and emissions controlled, and in many modern facilities computer control systems are utilized to achieve this.*

In 1987 the WTE facilities in the USA processed 13,700,000 tonnes of waste and produced 9510 gTEQ of dioxins. In 2012 WTE facilities in the USA processed 27,400,000 tonnes of waste and produced 3.4 gTEQ of dioxins. The 3.4 gTEQ of dioxins represented 0.54% of the controlled industrial dioxin emissions in the USA and 0.09% of all dioxin emissions from controlled and open burning in the USA.**

* http://energyrecoverycouncil.org/wp-content/uploads/2016/05/ERC-2016-directory.pdf

** https://www.sciencedirect.com/science/article/pii/S0956053X15300775?via%3Dihub

Economic Impacts of WTE

The global WTE market was valued at US$25.32 billion in 2013, a growth of 5.5% over the previous year. WTE technologies based on thermal energy conversion lead the market, and accounted for 88.2% of total market revenue in 2013. The global market is expected to maintain its steady growth to 2023, when it is estimated it would be worth US$40 billion. From a regional perspective, it is estimated that the Asia-Pacific region will register the fastest growth over this period, driven by increasing waste generation and government initiatives in China and India and higher technology penetration in Japan.*

In 2013, Eileen Brettler Berenyi, PhD did a study on the WTE industry in the USA and produced a report entitled *Nationwide Economic Benefits of the WTE Sector*. The main findings of the report are as follows:

- The WTE sector employs about 5,350 people nationwide. This number includes workers at specific sites, as well as off-site employees of the several regional and national firms that own and operate WTE facilities and local government personnel dedicated to plant oversight and maintenance.
- The WTE sector also creates an additional 8,600 jobs outside of the sector.
- Employees at WTE plants are technically skilled and are compensated at a relatively high average wage. For the purposes of this study a national average salary of US$85,700 (inclusive of fringe benefits) was used. Employees in the WTE industry receive about US$460 million in annual salary and benefits.
- The effect of this direct spending on employee compensation generated another US$429 million of compensation for workers across various associated industries.
- The waste-to-energy sector provides significant economic value in the communities in which these facilities operate. In addition to the revenues generated by the sector, WTE facilities provide stable, long-term, well-paying jobs, while simultaneously pumping dollars into local economies through the purchase of local goods and services and the payment of fees and taxes.

* https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf

** http://energyrecoverycouncil.org/wp-content/uploads/2016/03/130820-Berenyi-Natl-WTE-Economic-Benefits.pdf

WTE and Greenhouse Gas (GHG) Emissions

According to the 2016 Energy Recovery Council report *, WTE reduces GHG emissions in the following three ways:

1. It generates energy that otherwise would likely be generated by fossil-fueled facilities;
2. It diverts solid waste from landfills where it would have emitted methane for generations; and
3. It recovers metals for recycling, thereby saving the GHGs and energy associated with the production of products and materials from virgin inputs.

On average, the U.S. EPA has determined that WTE facilities reduce GHG emissions by one tonne of CO_2e for every tonne of MSW diverted from landfill and processed. CO_2e (Carbon dioxide equivalent) is a term for describing different GHGs in a common unit. For any quantity and type of GHG, CO_2e signifies the amount of carbon dioxide which would have the equivalent global warming impact.

The Energy Recovery report also states that WTE facilities generate carbon credits under the Clean Development Mechanism (CDM) of the Kyoto Protocol and voluntary carbon offset markets. Forty WTE projects in the USA have been registered with a combined annual GHG reduction of 5 million tonnes of CO_2e. Two municipally owned WTE facilities in Florida have been selling carbon credits into the voluntary market for several years.

The Kyoto Protocol was adopted in Kyoto, Japan and came into force in 2005. It is an international treaty that commits state parties to reduce GHG emissions based on scientific consensus that global warming is occurring and that it is extremely likely that human made carbon dioxide emissions have predominantly caused it. The CDM is one of the mechanisms in the Kyoto Protocol that provides for emission reduction projects which generate CER units which may be traded in emission trading schemes. Certified emission reductions (CER) are a type of emission unit.

* http://energyrecoverycouncil.org/wp-content/uploads/2016/06/ERC-2016-directory.pdf

Waste as a Renewable Resource

In the USA, thirty-one states, the District of Columbia and two territories have defined WTE as a renewable energy in various state statues and regulations. The renewable status has enabled WTE facilities to sell credits in renewable energy trading markets, as well as to the US federal government. *

Canada considers renewable energy sources as hydroelectricity, solar power, wind power and bio-energy. Canada's National Energy Board describes biomass energy generation as follows. "Globally, biomass generation is mostly attributed to solid biomass in the form of wood pellets and chips. Biogas, municipal solid waste, and biofuels are also used but less common." **

Although WTE is accepted in some jurisdictions as a renewable resource, not all jurisdictions agree with this approach. Generally, MSW is considered as a renewable source, because it cannot be depleted. Earlier in this paper it was stated that WTE projects are eligible for offset under the Clean Development Mechanism (CDM) protocol, by displacing fossil-fuel electricity generation and limiting uncontrolled methane release from landfill. However, in some countries like Germany, France and Italy, MSW is not considered 100% renewable, since portions of MSW consist of non-renewable elements. Hence, only the biogenic proportion of waste (food, paper, wood, etc. which typically represents greater than 50% of the waste stream) is considered renewable and this is reflected in the policies on energy extraction from waste.

* http://energyrecoverycouncil.org/wp-content/uploads/2016/06/ERC-2016-directory.pdf

** https://www.neb-one.gc.ca/nrg/sttstc/lctrct/rprt/2017cnddptnrnwblpwr/2017cnddptnrnwblpwr-eng.pdf

Role of Governments

There are various factors that affect a jurisdiction's policy on waste management and the use of WTE. Those factors include the following:

- Societal beliefs
- Level of development of the jurisdiction
- Remaining landfill capacity within its boundaries
- Dependence on the export of waste to other jurisdictions
- Public resistance to certain waste management options
- Political will/pressure
- Protection of the environment
- The requirement for energy and natural resources
- Financial resources
- Environmental pressure from failing waste management facilities

As a result of the factors influencing waste management policy, the implementation of WTE may or may not be implemented. In addition, the waste management policies which are selected by the local governments of a specific region, country or city (e.g. separated waste collection, recycling centers, waste import/export, etc.) can greatly influence the feasibility of WTE projects.

The following policy measures can be considered to encourage the development of WTE:

- Ban landfilling to ensure more waste is managed further up the waste hierarchy; as of 2015, 18 countries in the European Union implement some form of ban on the use of landfill for waste disposal and EU legislation has placed a binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030.*
- Raise the disposal fee at landfills to make it a less attractive option for waste disposal. In Sweden where land for landfill is available and affordable in some parts of the country, landfill fees are kept artificially high due to taxation and consequently Sweden is in the top 11 countries in the world in terms of its waste diversion and waste incineration rates.
- Provide government subsidies and incentives to produce heat and electricity from waste.
- Impose a carbon tax on fossil fuels to make the production of alternative energy sources more competitive.
- Consider WTE a renewable resource.
- Provide public education on WTE technologies.
- Engage local communities in order to receive project acceptance and support.
- Provide benefits to the local community that hosts a WTE facility; the benefits could be reduction of property taxes or the replacement or creation of community assets like fire halls and community centers.
- Ensure that each WTE facility has a visitor's center to enable local groups to see and learn about its operation.
- Ensure WTE facility staff receive the appropriate vocational training to be better prepared to engage with the public.
- Ensure that the WTE has clearly defined safety and emergency plans.

* http://ec.europa.eu/environment/waste/target_review.htm