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Response to GAIA's "Green Businesses and Cities at Risk

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As a society we can achieve the cleaner air, water, and soil that we all want. Working toward a more circular economy is in everyone's best interest. But it is only through a pragmatic approach rooted in scientific and engineering realities that we will achieve success. Some organizations are actually rooted, however, in ideology, and this rigidity only serves, ironically, to hinder our progress toward a cleaner environment.

Recently the Global Alliance for Incineration Alternatives (GAIA) released a report "Green Businesses and Cities at Risk"(Ponder *et al.*, 2017) that contains a number of misleading and factually incorrect statements. Their overall premise regarding sustainable waste management is erroneous and quite simply will lead to more waste going to landfills than ever before. This report continues along a path that GAIA has been advocating for years using flawed methods to arrive at conclusions that are disingenuous, distorted and untrue. If this were a one-time release, with the New School, it may be understandable, as the New School may not appreciate the data that clearly demonstrates thermal conversion of wastes must be part of the sustainable waste management solution. This report, however, is published by the Tishman Environment and Design Center at The New School, who have leadership on the Board of Trustees of GAIA. It is therefore clear that this report is not an independent, albeit incorrect, academic analysis, but rather an advertisement to disseminate misinformation about sustainable waste management solutions.

There is a need for experienced, quantitative science and engineering to guide decisions related to sustainable waste management. Lofty ideals and utopian schemes many times interrupt the practical, deployable solutions that currently exist to ensure the safest, most environmentally friendly management of society's garbage. This is not to say that ideal solutions should be dismissed, but it should be recognized that during the pursuit of the optimal solution, practical, immediate methods need to be engaged. The analog is to completely close all power generation that does not use perfectly renewable energy to generate power. The GAIA report is based on incorrect calculations and does not take into account the science and engineering of the real issues associated with managing the immense scale of the waste generated every single day. Furthermore, it does not propose a solution, only an idea, then proceeds to attack thermal conversion in ways that are preposterous. Furthermore it is completely against the Ocean Conservancy who espouse the idea of energy recovery as a key component of better waste management in the developing world. Specifically they state "Using a variety of waste-to-fuel (e.g., gasification) or waste-to-energy (e.g., incineration with energy recovery) technologies to treat waste in areas with high waste density" as a possible solution to reduce plastic debris from leaking into the oceans.

If policy makers are to follow the advice of the report, or any of GAIA's arguments, they will be faced with a situation in which the amount of waste going to landfills or enters the oceans actually greatly increases. A 2015 publication by Jambeck et al. stated that global "peak waste" will not happen before the year 2100. They predicted that by 2025, if waste management infrastructure does not improve, the amount of plastic waste available to enter the ocean from the land will increase by an order of magnitude(Jambeck *et al.*, 2015). Faced with this possibility, one can wait until "package redesign" allows for a perfect circular economy or use current systems to interrupt the flow of plastics into the marine environment. Therefore, practical methods must be used during the quest for a circular economy. In the case of sustainable waste management that means using all possible solutions in addition to prevention and reduction to minimize the environmental impact. This white paper will demonstrate how thermal conversion positively contributes to sustainability goals. The conclusions and findings are supported by facts and data that have been developed over the past decades through myriad scientists and engineers that possess the requisite skills to understand and assess the performance of waste management technologies.

The knowledge that we have developed in the area of sustainable systems, and in particular, sustainable waste management, has occurred through international collaborations, seminar and conference engagements, PhD and MS Theses, academic and industrially applied research and interactions with governmental agencies. Recognition of this expertise and knowledge has resulted in Castaldi receiving the Fulbright Global Award for the research involved in transforming waste materials, such as biomass and municipal solid waste, to energy and chemicals. The National Academy of Engineering Frontiers of Engineering Education appointed Castaldi as Fellow for the 2012-2013 academic year based on the work related to waste to energy. Two books have been published related to waste conversion technologies, as well as over 90 peer reviewed journal articles related to waste prevention and reduction, waste to energy and utilization of waste materials for energy or materials production. The extensive exploration and study of sustainable waste management options instills a passion in all of us to improve the environmental state of the planet for future generations. We work tirelessly to educate students and the public and disseminate the most accurate information possible. We do this because we recognize it is critical that everyone understands their role to live in the most sustainable way possible. Yet we must be led by the scientific findings and best engineering solutions of today to make the most meaningful contributions that benefit society as a whole.

Progress is only made when calculated risks are taken regardless of the endeavor. In the area of sustainable waste management the calculated risks are understanding the technologies to recover the embedded energy and materials in waste. Then to properly design the process where the technology operates in a way that satisfies the multi-constrained problem of meeting environmental protection goals, recovering embedded energy and materials to offset the extraction of virgin resources and maintain the cleanliness, thus health, of society. The overall theme of GAIA (especially present in their latest report) is to stifle progress toward a sustainable, circular economy by instilling doubt and fear in public perception about thermal conversion of wastes. The effort by GAIA to halt development and deployment of thermal conversion systems is in direct opposition to sustainability goals. If GAIA's efforts are successful the logical outcome will be a substantially increased amount of waste going to landfill, which has been scientifically demonstrated to be the least desirable solution for waste(Castaldi, 2014).

There are only two processes that can be used to manage the "residual waste" - i.e., the waste that is not targeted by source separation reuse and recycling programs. These well-established alternatives to treating mixed or residual municipal solid waste (MSW) are thermal treatment, aka Waste-to-Energy, and Mechanical–Biological Treatment (MBT). There is also a third option developing for small-to-medium scale MSW treatment and the MSW treatment in developing countries that will complement current WTE (UNIDO, 1996; Zhao *et al.*, 2014). In thermal treatment the heat generated by combustion or gasification is transferred to steam that can flow through a turbine to generate electricity. This process is called waste-to-energy (WTE). Thermal treatment also enables the recovery and recycling of metals and minerals in the waste that are not targeted by source-separation recycling programs and thus would otherwise be disposed in landfills. Thermal treatment systems can reduce the mass of waste requiring disposal by 90 percent if the minerals in the ash are recovered for road construction. In this regard, thermal treatment systems used in conjunction with robust source separation recycling systems can provide a true and proven "zero waste" alternative. Importantly, WTE differs from incineration because of the energy generation component. It has been proven through carbon-14 methods (ASTM D6866 protocol) that typical MSW WTE stack emissions, that routinely meet the Maximum Achievable Control Technology (MACT) standards, contain between 40-65% biogenic CO_2, i.e. renewable bio-carbon. If the GHG savings from recycling 50 pounds of metal from every ton of MSW processed in a WTE facility are included it is evident that every ton of MSW processed in a WTE facility avoids a ton of CO_2 equivalent emissions(Brunner and Rechberger, 2004, 2015).

The general concept of zero waste is an excellent goal to strive toward; leading to a perfect and optimal cycle that allows materials to be forever used once extracted from the environment. Currently, however, this is not possible for many reasons spanning the limitations of technology to human behavior. Therefore, until this perfect cycle is achieved in practice, society has the responsibility to employ all solutions available to sustainably manage material that becomes waste. Unfortunately, advocates committed to the perfect zero waste goal do not propose a way to achieve zero waste except giving vague guidance such as; “redesign products and packaging to minimize waste creation upstream”. That guidance is based on a false premise that recycling can sustainably manage all waste until such redesign and repacking occurs. The reality is that reuse and recycling cannot achieve zero waste to the scale that is required.

In terms of ultimately achieving zero waste through redesign, to a large extent, redesign has been done through material replacement of glass and metal with plastics. This has led to a decoupling between MSW volume and weight increases and economic growth indicated by personal consumption expenditure (PCE). In other words, the redesign of certain consumer packaging using plastics has reduced the rate of MSW generation, even as economic growth has increased. A familiar initiative from Apple has focused on product redesign and packaging. Their Brightstar|Apple Renew(*Apple Renew,* 2016) program does not include iPhone, iPhone 3G, iPhone 3GS, iPhone 4 devices, yet there are many of these devices remaining. However, one can still send those to Sims Recycling Solutions domestic processing facilities, where they state a “zero waste **to landfill**” policy. Here again, there is a major manufacturer putting resources behind redesign and recovery yet recognize there is no such thing as perfect zero waste.

Numerous statements are made in the GAIA report such as "*waste-to-energy," "zero waste to landfill," or "refuse derived fuel" replace reduction and recycling with the burning of valuable resources under the guise of zero waste*". However, for most communities, thermal treatment is used only to process residual waste, i.e. waste that is not targeted for recovery through source-separation recycling. There is a wealth of data across the country and around the world demonstrating that the use of WTE actually results in an increase in recycling. Thermal treatment enables the recovery of additional materials not targeted by source separation recycling programs. Thermal treatment is by definition only used to process residual waste and therefore does not compete for materials that can be recovered and sold through source separation recycling.

In this regard, information provided by the UK's Department for Environment Food & Rural Affair (DEFRA) shows that recycling, composting and waste to energy are complementary. For example, Austria achieved 70% recycling (including composting) with 30% of waste going to WTE in 2010; likewise, Germany reached 62% recycling with a 38% WTE rate; and Belgium achieved 62% recycling alongside 37% incineration(Sara, 2016). The landfill ban in these countries has certainly helped achieve these high numbers. It should be noted that "recycling rate" is often vague, confusing and flawed, therefore many times the values are over-estimates of the actual amount of material sent to recycling. The recycling rates achieved in these countries are very close to the 75% diversion goals set by WTE opposition groups in the U.S. The difference is that the high recycling rates have been achieved in countries that included WTE in their waste infrastructure whereas in the U.S., opposition groups believe that this magnitude of recycling diversion can only be achieved if WTE is eliminated. The coexisting management options of recycling and WTE in the cited European countries result in less than 1% of waste going to landfills in those countries. By comparison, the UK sent only about 12% of waste to WTE facilities while achieving a 39% recycling rate, meaning nearly 49% of waste was sent to landfills over the same time period. Although currently some EU countries have more WTE capacity than needed to manage their individual waste, there has been an import of material from other countries with insufficient capacity in WTE. Therefore, this has led to an overall reduction in material sent to landfills, thus reducing the negative impacts of landfills, and has not impacted the recycling rates. The data shown in Figure 1 provides the information for more countries across Europe. It is clear that the use of WTE correlates positively to increase recycling and actually reduces the amount that goes to landfilling.

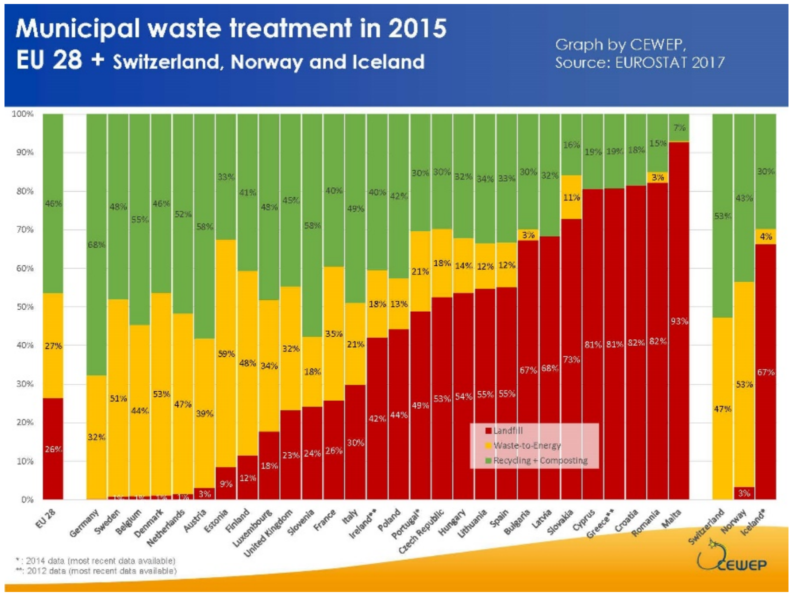

Figure 1. *Comparison of waste management options demonstrating WTE diverts waste from landfills, not recycling*

In the United States of America, approximately 35% of MSW was recycled and 13% went to WTE in 2014(Environmental Protection Agency *et al.*, 2014). This has been relatively constant over the past five years but counties and municipalities that utilize WTE consistently show an increased recycling rate. Figure 2 quantitatively demonstrates that communities in the USA that employ WTE achieve better recycling rates than the statewide rate. These examples, as well as numerous other studies(Berenyi, 2014; Castaldi, 2014; Brunner and Rechberger, 2015), unambiguously demonstrate, using measured data, that WTE will discourage recycling may have been the case in the 1970's but has not been true for nearly 25 years.

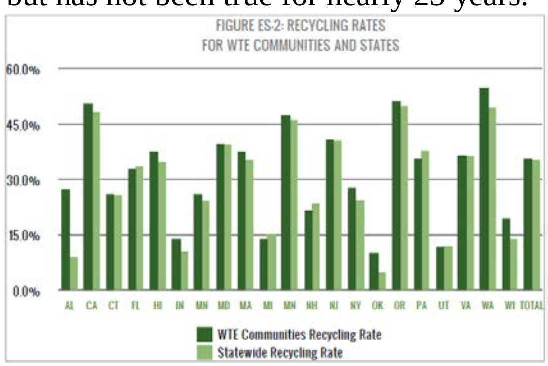

Figure 2. *Data showing U.S. communities that employ WTE have similar or higher average recycling rates compared to statewide*(Berenyi, 2014).

Why everything cannot be recycled today.

Complete material recovery (i.e. material **collection**) followed by recycling of paper and plastic waste streams is crucial for the success or failure of achieving zero waste targets. The highest recovery (collection) of material from paper and plastic waste streams reported in the U.S. and Europe are 85 % and 73 %, respectively. However, this means that there is still a remaining 15 % and 27 % of paper and plastic waste that is not recycled or reused indicating it is not possible to completely recycle all paper and plastic(FDEP, 2013; Rigamonti, Falbo and Grosso, 2013). This is due to major technical issues associated with the limited recycle of paper and plastic as well as the limitations to collection systems. For example, in the U.S. the state-of-theart recycling equipment used for paper had a stagnant recovery rate from 2008-2013 of 66.4 % (46,000 tonnes), even though the amount of paper available for recycle is near 70,000 tonnes. Plastic recycling is a similar case where nearly 79 % cannot be technically recovered due to problems associated with specific property requirements for final recycled products(Sharma *et al.*, 2017), yet in certain countries of the EU the plastic recycling rate reaches nearly 45%. Thus in most cases, a significant part of the MBT output is combusted for energy recovery. Therefore, thermal processing is a necessary component of achieving zero waste. Furthermore, materials with hazardous compounds such as flame retardants should not be recycled, since those compounds can end up in new consumer products, including baby toys and eating utensils(Miller *et al.*, 2012; Blum, 2016). Importantly, these limitations are independent of the actual market available for the recycled material. The highest material diversion reported by Waste & Resources Action Programme (WRAP) and Zero Waste Europe (ZWE) are 82 % and 85 %, respectively. This indicates that even if markets were available to take the recycled material, approximately 15% would still be a waste thus, again proving zero waste is not possible.

Ultimately, the goal of a zero waste society and circular economy is that products are redesigned in their infancy prior to manufacturing so that they can be 100% recycled or reused in the post-consumer/end-of-life stage of their product lifecycle. If and when all products are designed as such, it must also be recognized that all recyclable products have a lifespan. There is a threshold to how many times a recyclable product can be recycled before it cannot be recycled again because it technically fails and is of no economic value. An example of this can be found when paper is recycled. Data shows that after three to four recycle iterations, the recycled paper fiber becomes too short and weak to endure further recycling(Sharma *et al.*, 2017). That demonstrates that even quality fiber paper eventually will enter the waste stream because there is a finite number of recycle iterations before it becomes technically infeasible to be recycled again. That fiber material is truly at the end of its life and must be disposed. Possibilities of producing a compost from this material will be contaminated from the inks and glues intimately mixed into the material.

Emissions Comparisons

Another statement in the GAIA report demonstrates the inability of the authors to understand the data regarding emissions. The statement “A 2011 New York Department of Environmental Conservation (NYDEC) study found facilities burning waste in the state released up to 14 times more mercury and more than twice as much carbon dioxide per unit of energy than coal plants” is wrong. Throughout the report there are claims that WTE is more polluting and toxic than coal power plants. Specifically, the following statements were made: “Incinerators emit more CO_2 per MWh than coal-fired plants”, “Incinerators have been shown to emit CO_2 at 2.55 times the rate of coal power plants”, “…facilities burning waste…released up to 14 more times more Hg and more than twice as much CO_2 per unit energy than coal plants”. This myth that WTE is more environmentally polluting than coal plants has been developed based on a calculation that is wrong(Michaels, 2007). In addition, the flue gases produced by WTE, as in other combustion systems, are thoroughly treated to meet regulated emissions standards.

Based on the NYDEC, *Comments to New York State Public Service Commission in the Matter of the application of Covanta Energy Corporation, August 19, 2011*, a calculation was done that is wrong. However to determine that, one must spend the time to get the data used by the NYDEC and redo the calculations properly. Specifically the authors of the public comment use emissions generation data from one year and power generation from another year for WTE facilities, yet use data from the same year for both emissions and power generation for the coal facilities. Since this public comments were not peer reviewed, the mistake was not known at that time. For example, their ratio of annual pounds of NO_x emissions per annual megawatt-hour (lb NO_x/MWh) is reported as 6.75 whereas the actual value for 2009 data is 1.8. The current ratios for the most updated data for the emissions, referred to by the NYDEC, encompassing all WTE and coal facilities in New York State can be found in Table 1. In addition, greater than 99.9% of the HCl and heavy metals are removed from the WTE flue gas prior to release. Specifically the data for 2009 are the correct values that should have been used by NYDEC in 2011. It is important to recognize in the U.S. that nearly 2/3 of the CO_2 emissions from the MSW plant is renewable, although in Europe it is now between 30-50% -see more detail below in the section “Benefits of WTE on greenhouse gas reduction”

Table 1. ***Correct data for 2009 and 2014 of MSW and coal plants in New York State.***

	-------- Average NO_x [lb/MWh] --------			-------- Average SO_2 [lb/MWh] --------			-------- Average CO_2 [lb/MWh] --------		
	MSW Plant	Coal Plant	ratio MSW/Coal	MSW Plant	Coal Plant	ratio MSW/Coal	MSW Plant	Coal Plant	ratio MSW/Coal
EPA 2009 data	4.0	2.2	**1.8**	6.5	9.4	**0.7**	2148.7	1945.0	**1.1**
EPA 2014 data	3.8	2.5	**1.6**	0.7	8.2	**0.1**	1652.3	2037.1	**0.8**
Percent change of average emission from 09-14	-4.0	11.5		-90.0	-0.13		-23.1	4.7	

One does not need to necessarily redo calculations to determine the accuracy or validity for emissions comparisons. There has been work done previously to document the emissions values from MSW and put them into context compared to other facilities generating power. Figure 3 below is taken from a peer reviewed proceedings from the North American Waste to Energy Conference (NAWTEC). The peer review process involved engineers and scientists who are experts in the area of power generation, combustion and pollution control equipment. The information in Figure 3 was published and presented in 2005 and is readily available in searchable databases. That data is consistent with Table 1 showing facilities that use MSW for power generation produce lower emissions than coal facilities. In addition, it should not be forgotten that facilities generating power from MSW are also diverting that material from landfill.

TABLE 3

Waste-to-Energy and Fossil Fuel Power Plants — Comparison of Air Emissions

Fuel	Carbon Dioxide	Sulfur Dioxide	Nitrogen Oxides
	Pounds per Megawatt—Hour		
MSW	837	0.8	5.4
Coal	2,249	13	6
Oil	1,672	12	4
Natural Gas	1,135	0.1	1.7

Figure 3. *Data published comparing emissions from MSW to fossil fuel power plant in 2005 for the entire U.S.*(O’Brien, 2006)

The information disseminated by GAIA on facilities producing a SpecFuel (an engineered fuel product derived from MSW) from waste is misleading and does not provide all the information. Emissions measured from an actual test to determine the impact of SpecFuel on the cement kiln from the SpecFuel produced by the facility near San Antonio, Texas referred in the GAIA report demonstrated improved environmental performance. Results from the industrial scale test showed a 34% reduction in SO_2 and 65% reduction in NO_x concentration in the process gas when co-firing 84% petcoke and 16% AF by weight, as compared to using 100% petcoke(Zhang, 2013) and is similar to other findings reported in peer reviewed literature(Kara, 2012). The beneficial effect of co-firing with AF was confirmed by a review of peer reviewed literature where environmental monitoring showed reductions of nearly 60% of WHO-TEQ in vegetation samples when a cement kiln was operated with 15% RDF and 85% classical fossil fuel compared to 100% fossil fuel(Aranda Usón *et al.*, 2013).

Misinformation about the Hefty® Energy Bag™ will result in poorer waste management

The Hefty® Energy Bag™ program works to collect non-recyclable plastics converting them into an engineered fuel source that can be used to offset fossil fuel. This novel approach seeks to utilize the embedded energy of these materials for systems such as process boilers and cement kilns. The authors of the GAIA report disparage this idea as a "misguided approach to waste management" yet currently the only disposal option is to landfill the material. The GAIA stance on the Hefty Energy Bag program ultimately hurts efforts towards a circular economy. First it must be made clear that over the past two decades the concept of Industrial Ecology has been firmly developed to consider industrial processes and the environment as a joint ecosystem. To improve this ecosystem there has been extensive analyses, studies and experiments that have unambiguously proved that the appropriate waste management and its integration into the production network as both material and energy is the foundation for such improvement. An excellent peer reviewed document that explains this concept and provides extensive reference reading can be found in Ghisellini et al.(Ghisellini, Cialani and Ulgiati, 2016). The Hefty Energy Bag program is exactly aligned with that foundation to improve the ecosystem, it returns materials and energy back into the production cycle. Dow Chemical, their partners and the cities of Bellevue and Omaha, Nebraska should be commended for their efforts to establish a process of preventing the bags from going to landfill where the material and energy will never be recovered and virgin materials will fill their place when new products are made. The statement by GAIA "…so-called 'hard to recycle plastics'" only further demonstrates their inability to understand the complexities associated with recycling plastics. Not all plastics (film and multilayer) are targeted by source-separation recycling programs. It is not only related to the individual waste generator (i.e. you and me) that must be conscientious and informed enough to completely source separate certain plastics but is heavily impacted by market economics, consumer preferences and technology limitations. See the above section and peer reviewed references therein on *Why everything cannot be recycled*.

The use of waste, in particular RDF/SRF/EF produced during the Hefty Energy Bag project, in cement kilns has been documented by our research and others to reduce greenhouse gases compared to conventional fueling operations. Direct analysis of EF material prepared by the same facility near San Antonio Texas, referred to earlier, resulted in a renewable energy content between 60 to 81%(Awad, 2015). There were savings associated with emission costs by using MSW in lieu of coal: up to ~3.3% for NO, ~20-47% for NO_2, and ~95% for SO_2 (McPhail *et al.*, 2014). Analysis of actual test data by EEC|CCNY on a cement kiln demonstrated a 34% reduction in SO_2 and 65% reduction in NOx concentrations in the process gas when co-firing 84% petcoke and 16% RDF by weight, as compared to using 100% petcoke. The Hefty Energy Bag program has diverted six tons of non-recyclable plastics from landfills from the effort in

Omaha and the University of Nebraska. Omaha recognizes that while plastics are ideal for pyrolysis systems, the practical option currently is to send them to facilities that can use the energy and offset the extraction of crude(Sobetski, 2017).

Benefits of WTE on greenhouse gas reduction

There are a number of technologies that can be used to reduce greenhouse gas emissions, such as anaerobic digestion and biomass fuel systems. However WTE also reduces greenhouse gases. New policies to encourage WTE can have a sizable effect on reducing the nation's greenhouse gas emissions. In fact, nation-wide use of the WTE technology can become one of the big contributors to America's carbon dioxide reductions, accounting for as much as 325 million tons of CO_2 or 5% of the total U.S. emissions in 2006. The EPA concluded WTE now produces electricity with less environmental impact than almost any other source(Horinko and Holmstead, 2003).

Again there are numerous studies, both calculations and measured emissions, that unambiguously quantify the amount of GHG emissions savings obtained using WTE. For example, that California Air Resources Board (CARB) concluded that the MSW disposed of in the three WTE facilities in California results in net negative GHG emissions, ranging between -0.16 and -0.45 MT CO_{2e} per ton of waste disposed. Figure 4 provides the individual savings for each WTE facility that was operating in California in 2014.

Table 5: ARB Staff Preliminary Estimates of Net GHG Emissions from California MSW Thermal Facilities*

(MTCO2e/Short Ton Waste)

Facility	Waste (TPD)	Non-biogenic MT CO2E Emissions	Energy Credit MT CO2E[1]	Metal Recycled (Tons)	Metal Recycling Credit MT CO2E[2]	Avoided Landfill Methane Emissions MTCO2e[3]	Net MT CO2E per Ton Waste
Covanta Stanislaus	800	79,590	-49,740	5,690	-10,240	-70,080 to -154,760	-0.17 to -0.46
Commerce Refuse to Energy	360	53,760	-26,000	920	-1,660	-31,540 to -69,640	-0.04 to -0.33
Long Beach SERRF	1380	115,790	-81,390	6,500	-11,700	-120,890 to -266,960	-0.19 to -0.48
Total	2,540	249,150	-153,740	13,110	-23,600	-222,500 to -491,360	-0.16 to -0.45

1 Uses 2009-2010 average CA grid emission factor of 668 lb. CO2e per MWh, and assumes facilities produce 85% of rated power capacity per Table 1.
2 Uses a metal recycling credit of 1.8 MT CO2e per short ton of ferrous metal.
3 Estimated avoided landfill methane emission 0.24 to 0.53 MTCO2e/MT

Figure 4. *CARB's analysis showing specific WTE facilities' ability to reduce GHG emissions*((CARB), 2013)

These savings arise from electricity produced from the WTE that offset electricity production from facilities that rely on fossil fuels. The waste is diverted from landfill and WTE facilities recover metals that are recycled. Finally a recent UNEP report "District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy" states that Paris currently meets 50% of its heating needs by three WTE plant that results in avoidance of 800,000 tons of CO_2 emissions each year. Figure 4 also includes the metal recycling credit because WTE plants recover nearly 700,000 tons of ferrous metal for recycling. That avoid CO_2 emissions and saves energy compared to the mining of virgin materials for manufacturing new metals.

Difference between WTE and incineration

There is a large difference between incineration and WTE that often is overlooked or not well understood. The main difference is the purposeful design of the system that differentiates them. An incineration system is designed to thermally destroy a waste material whereas a WTE system is designed to produce electricity and useful steam by thermally converting a waste material. A second, very important aspect, is that an incineration system is not required to produce energy and many actually consume energy to destroy the waste feedstock. A WTE facility typically produces an average of 650 kWh of electricity per ton of MSW and approximately 600 kWh of steam per ton of MSW that can be used for heating or cooling operations. The only similarity between incineration and WTE is that they both combust the waste with air and strive to achieve a well-established performance metric comprised of temperature, time and turbulence, typically referred to as "the 3 T's". This metric has been demonstrated to be effective in establishing robust combustion performance covering a large range of materials. Particular to MSW, WTE systems are designed for the complete destruction of any living organisms therefore they operate with a combustion gas temperature of greater than 850 °C and a residence time of greater than 2 seconds with a significant amount of turbulence (i.e. mixing) of the combustion gases and incoming air. The final off-gas is treated in an air pollution control system before exhausted to the atmosphere.

There is a practice by GAIA to lump all thermal conversion systems into one category and label them incineration. That practice illustrates the complete lack of understanding of the systems that are used to convert waste materials that currently cannot be recycled to energy and fuels while simultaneously extracting materials (e.g. aluminum, iron, copper) that are extensively used in the manufacture of consumer products. Every 1000 kg (one ton) of MSW converted to energy produces about 250 kg of bottom ash (that can be beneficially used) and 20-30 kg of fly ash that is safely discarded in landfills. The Enerkem process in Edmonton Canada produces methanol and ethanol from the carbon contained in non-recyclable waste(Wright and Feinberg, 1993; Chornet *et al.*, 2010). Regarding specific waste streams, such as plastics, there is a large body of peer reviewed literature(Sharuddin *et al.*, 2016) as well as large scale demonstration systems that thermally convert non-recyclable plastic waste to useable fuel or chemicals(Al-Salem *et al.*, 2017). More specific to plastics; approximately 82.7% or 32.5 million tons of non-recycled plastics in the US is landfilled. A recent study completed by the Earth Engineering at City College confirmed that non-recycled plastics are more energy dense than conventionally used energy resources such as coal, petroleum coke, and wood. Furthermore, it was concluded that plastics found in the waste stream retain most of their energy value even when contaminated with moisture and other substances found in waste(Tsiamis and Castaldi, 2016). Specifically the embedded energy content in non-recyclable plastics is 35.7 MJ/kg. That value is 19% higher than petroleum coke, 37% higher than U.S. coal, and 87% higher than wood and thus serves as an excellent material to be used to offset the extraction of those fuels.

Modern day WTE facilities have their roots in incineration going back to the 18^{th} century where large cities could not manage the increasing waste generation and consequently were dumping it into their rivers and waterways. Therefore they constructed the simple incinerators, consisting of a furnace and a stack with the main goal of greatly reducing the volume. That practice significantly reduced the outbreaks of cholera and typhoid fever that were prevalent at the time. However, it was quickly recognized that emissions from the stack may have different health effects that were not as acute as the typical disease vectors stemming from untreated

MSW(Brunner and Rechberger, 2015). The improvements in MSW combustion development have resulted in modern day WTE facilities being recognized by the EPA nearly a decade ago; "The performance of the MACT retrofits has been outstanding." Emission reductions achieved for all CAA section 129 pollutants have been 90% or greater, except for NOx, from 1999 – 2005 and are still being decreased(Stevenson, 2007). Therefore just as todays jet planes have their roots in the Wright Brother's flying machine, WTE facilities are completely different from incineration of the past.

Difference between combustion, gasification and pyrolysis

Focusing on WTE systems there is a range of technologies that can be considered for power and steam generation from waste streams. These fall under the broad classification of thermal treatment or thermal conversion and can be categorized under combustion, gasification or pyrolysis. These thermal conversion technologies all rely on high temperatures to achieve the conversion, yet there are four critical differences that do not make them equal. The first major difference is the amount of oxygen or air that is combined with the waste stream. That combination results in different chemical composition of the final products during the conversion, which is the second major difference. A third important difference is the waste that is used to operate the system and any associated preparation required. Finally there is the fourth difference related to the scale of operation and the availability and performance track record.

The first two differences between the thermal treatment systems are related, therefore, they will be discussed together. Combustion systems utilize an excess amount of air, from 50% to 100%, to fully oxidize the MSW components introduced to the boiler. That excess air helps ensure all the MSW is completely converted to a flue gas primarily comprised of CO_2, H_2O, O_2 and N_2 in the approximate amounts of 11%, 15%, 8% and 66% respectively and ash. Combustion also releases the full embedded energy in the MSW feedstock. Conversely gasification operates in a regime that does not supply enough air to completely convert the MSW to CO_2 and H_2O so that only a portion of the embedded energy is realized. Thus the flue gas is composed of mainly CO and H_2 but also contains some CO_2 and H_2O. Importantly this type of operation results in a solid residual that contains a large percentage of char and therefore does not achieve the same volume reduction or release as much heat as combustion. Finally pyrolysis operates without any air therefore typically produces a flue gas composed of CO, H_2 and CH_4 with a significant solid residual remaining and often a liquid product such as an oil. The pyrolysis configuration requires that heat be supplied to the system either from combusting some of the flue gas (CO, H_2 & CH_4) or through heating via another means. The flue gas produced from combustion can only be used for power generation or heat exchange. The flue gas produced from gasification can either be further combusted for power generation or heat exchange or sent to another process that converts the chemical constituents of the flue gas to a particular product. The only current example of converting gasification flue gas to a useable product is the Enerkem process that produces methanol and ethanol by further reacting the flue gas with a downstream Fisher-Tropsch reactor system. Currently there are no commercial systems that pyrolyze MSW.

The third and fourth main differences can also be discussed together because of the intertwined nature of process requirements and scale of operation. Systems that employ combustion need no processing of the waste and can convert "as-received" MSW in standard black garbage bags or other common forms. Therefore, the scale of operation of "as-received" MSW combustion

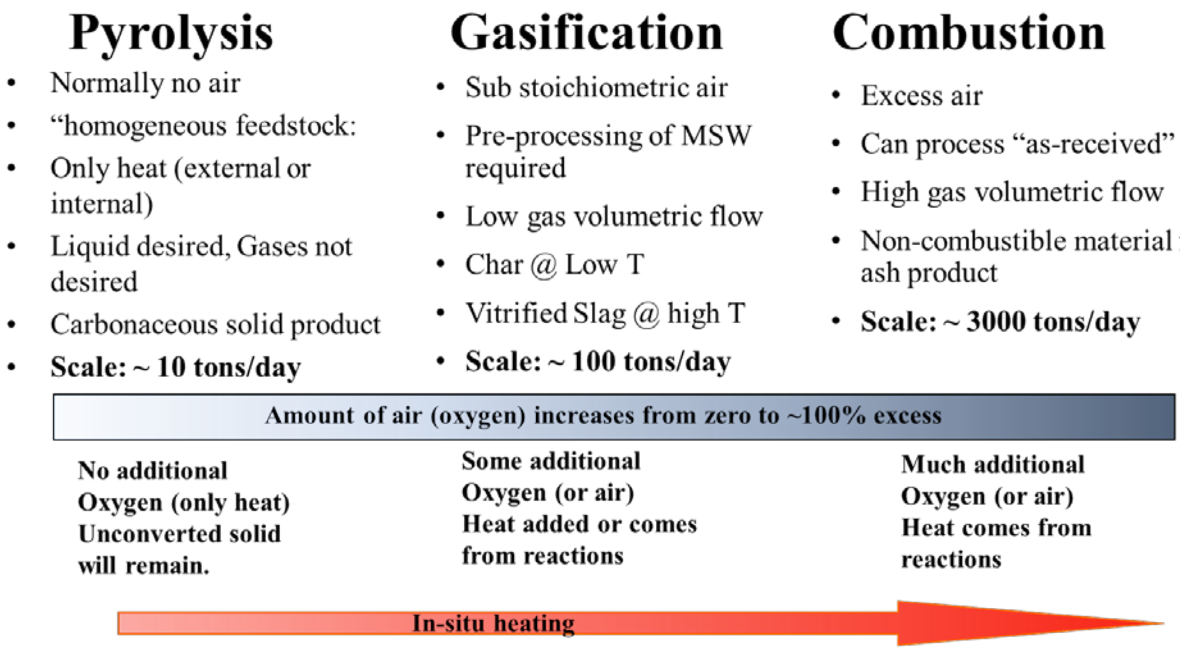

Figure 5. Differences between thermal conversion systems showing they are not all the same.

systems is typically 3000 tons per day although in Europe, plants tend to be much smaller. Gasification systems typically use a processed MSW stream such as a residual from a material recovery facility (MRF). The only exception is the Covanta Low Emissions Energy Recovery Gasification (CLEERGAS™) system that can accommodate "as-received" MSW. The residual MRF stream is referred to as a refuse derived fuel (RDF), solid derived fuel (SRF) or engineering fuel (EF). RDF/SRF is typically composed of organic material such as plastics and biodegradable wastes because the glass, metal and paper have been removed. EF is derived from RDF/SRF via additional processes to achieve a certain energy, moisture or chemical composition. Gasification systems typically operate on the scale of 100's of tons per day and generally require extensive processing of the MSW to produce the RDF/SRF or EF feedstock. Finally, pyrolysis conversion systems require a more "homogeneous" feedstock obtained from the waste stream. A common material, well suited for pyrolysis, is plastic material that cannot be recycled or is not for some particular reason. Therefore although the plastic feedstock may be variable regarding the types of plastic resins, the stream is all plastic and contains very little paper, organics, metals and glass. Since this feedstock requires significant process of the waste stream and the conversion system is designed to operate on a specific "homogeneous" stream, pyrolysis is normally operated at the scale of about 10 tons per day(Niessen, 2010; Klinghoffer and Castaldi, 2013; Reddy, 2016). Figure 5 provides a summary view of the different thermal treatment systems briefly described above.

Therefore the technologies developed for the thermal treatment of MSW possess significant differences. The attributes associated with each technology make them suitable for different waste management scenarios. Combustion can accommodate all MSW as-received from the collection trucks and therefore is the most widely used and has the longest proven reliable performance record. Gasification and pyrolysis are better suited for smaller amounts of specific waste streams and do not have a commercially proven record thus have a higher associated risk. To categorically include all thermal conversion systems as one type of "incineration" reveals the lack of knowledge required to understand the important differences. That type of generalization is similar to equating a hybrid, fuel-flexible car that can operate with biofuel or natural gas with a car that is propelled with a conventional combustion engine operating on gasoline or diesel.

The disingenuous labeling of the EPA NHSM rule as a "loophole".

The gross mischaracterization by GAIA of the EPA NSHM rule shows either their complete lack of rigor when developing arguments or their contempt for the EPA's extensive, deliberate, time-consuming process that ensures all input is given due consideration. EEC|CCNY has provided comments and feedback to the EPA regarding other rulemaking in the past. Those experiences confirmed the rigor and attention the EPA staff apply when developing rules. The mischaracterization by GAIA only serves to create doubt in the public regarding the actions and activities of the EPA. Since the EPA has been established it is clear our environment has improved and for GAIA to disparage such an effort is appalling.

The ruling developed by the Environmental Protection Agency (EPA) was initiated in January 2009 through an advanced notice of proposed rulemaking (ANPRM) under sections 112 and 129 of the Clean Air Act (CAA) for public recommendations on a number of specific questions concerning the meaning of "solid waste" under the Resource Conservation and Recovery Act (RCRA). The EPA specifically recognized the beneficial use of secondary materials programs in in Europe and Japan regarding their use of these secondary materials since the 1970s and considered it a positive step toward sustainable environmental protection. Furthermore, EPA explicitly recognized the "inherent resource recovery value in the generation/production of heat, energy, and/or marketable products" from secondary materials ranging from biomass to scrap plastics(USEPA, 2010).

EPA proposed its non-hazardous secondary materials ("NHSM") rule in June 2010 after consideration of submitted comments and supporting white papers. The proposed rule focused on identifying waste materials, including scrap plastics, that provided the most value during re-use as fuel or feedstock. These would have similar air pollutant emissions when compared to traditional fuels. Importantly EPA wanted to ensure the rulemaking addressed the concept of legitimate recycling due to their past evidence of "sham" recycling (when handlers claim they are recycling when they really only treat and dispose) and wanted to prevent that practice from continuing. EPA finalized the NHSM Rule in March 2011 with several changes in response to thousands of public comments. Public comments were separately addressed in detail in a 275 page Response to Comment document(USEPA, 2011). The EPA specifically responded to "misconceptions" about the "*use of secondary materials used to produce a safe fuel product that is a valuable commodity or that a secondary material that is burned in a combustion unit does not necessarily have high levels of contaminants*"(USEPA, 2011) (comment 3a-A1-3, p.35). The U.S. Court of Appeals for the District of Columbia Circuit upheld a legal challenge to the NHSM Rule by industry groups who primarily objected to certain recordkeeping requirements. Interestingly environmental groups did not challenge the rule in court. EPA subsequently proposed clarifying amendments to the rule in December 2011, introducing additional measures to prevent sham recycling and providing categorical determinations for specific exempted materials. After reviewing public comments again, the EPA finalized the amendments in February 2013. It added more materials to its list of categorical non-waste exemptions in February 2016. Since the original 2011 rule, studies continue to show that scrap plastics are underused and are a valuable resource for energy recovery. Although many people recycle, the vast majority of plastics still go to landfills. According to EPA, only 9.5% of plastics generated are recycled with 15% combusted and 75.5% discarded in landfills(USEPA, 2016). This is exactly the problem the Hefty Energy Bag program is working to address.

Some environmental groups have criticized the NHSM Rule, but unable to assail the rule on its own terms, they have grossly mischaracterized it. Far from the "loophole" that some critics claim, EPA developed the NHSM Rule and its amendments over a four year process spanning two different presidential administrations while responding to 42,464 public comments. In its rulemakings, EPA addressed public comments on subjects ranging from the how it would balance the various goals of the NHSM Rule, specific NHSM fuels, the types facilities that would combust those fuels, and air pollutant emission standards. Therefore, it is not a "loophole." The entire purpose of the NHSM Rule is to exempt categories of non-hazardous fuels and feedstocks from being unnecessarily classified as solid waste if they can be combusted in an environmentally beneficial way. This was not an oversight, an ambiguity exploited to avoid regulation, or fine print slipped into the rule by lobbyists. Rather, the NHSM Rule and its amendments are well-thought-out products of a lengthy and robust deliberative process in which thousands of stakeholders representing the full range of ideas participated. As the EPA explained, the NHSM Rule is a set of "standards and procedures to be used to identify whether non-hazardous secondary materials are solid wastes when used as fuels or ingredients in combustion units(USEPA, 2010).

Combustion is subject to stringent air emission standards and WTE facilities comply exceedingly well with Maximum Achievable Control Technology (MACT) rules. Facilities burning NHSM fuels are subject to National Emission Standards for Hazardous Air Pollutants ("NESHAPs"), a stringent regulatory regime that bases MACT emission standards on the top performing emission sources. NESHAPs are generally considered one of the most stringent air pollution control schemes under the Clean Air Act. In addition, all non-hazardous fuels are subject to the EPA's "comparable contaminant" requirement. This means that the air contaminants that would be produced from the NHSM fuel must be similar to, or lower than, traditional fuels that could be combusted in the same unit. Fuels generated as byproducts of an industrial process may be combusted so long as they remain "within the control" of the generator, meaning they are created and combusted at the same facility or another facility owned by the same company. These types of non-hazardous fuels must also meet the EPA's "legitimacy criteria" to make sure that materials are not disposed of under the guise of recycling (i.e. sham recycling). These fuels must be (1) managed as if they were a commodity that is valuable to the company; (2) have a meaningful heating value and be used in a unit that recovers energy; and (3) comply with the "comparable contaminant" requirement.

The United States generated 33.25 million tons of plastics in 2014 with only 9.5% percent of that being recycled(USEPA, 2016). Although many would like to increase recycling, there are few ideas that can dramatically expand the scope of recycling programs, therefore practical solutions are required now to keep plastics out of landfills. Current initiatives to increase recycling may yield marginal improvements, but the increased production of plastics is far outpacing increased recycling rates(USEPA, 2014). Currently some pyrolysis and gasification systems under development may turn unrecycled plastics into fuels and other valuable products while reducing landfill disposal. This advances sustainability in a realistic way while adding value to the economy.

Conclusions

GAIA has again released a document that contains several factual errors that will only hurt progress, risk taking and pragmatic solutions towards being smarter today with our resources. It is important that GAIA be identified for their misrepresentations because stifling efforts that comprise a holistic solution toward sustainable waste management is irresponsible. There are no simple solutions. We need new and novel approaches, guided by sound science and engineering principles, to make progress towards living a sustainable lifestyle. One of the fundamental tenets of chemical engineering is closing a material and energy balance. Use of energy and materials from waste/secondary materials does just that. It is unclear and frankly quite surprising, why so-called environmental groups resist the implementation of processes that can handle the rate of waste generation, produce energy, recover metals, preserve land and avoid mining and use of fossil energy. The data and track records are clear that WTE and other techniques to extract energy and materials needs to be increased to help the US progress on a more sustainable path. In addition, different approaches must be tried such those of SpecFUEL and the Hefty® Energy Bag™ to affect progress. In a zero waste world, all products that are manufactured and consumed would return back into the supply chain at their end-of-life, thus creating a continuous life cycle for products with no waste being generated. Although it is debatable that it can be achieved, this is an ideal that should be pursued but it does not mean that, in the process of getting there, one disparages the technologies that help manage with the immediate and growing waste pollution issue.

This white paper discussed why current sustainable waste management must include energy recovery if communities want to approach their "zero waste" targets. Current recycling cannot divert all waste from landfills due to limitations in the technology as well as the markets. Composting and anaerobic digestion can only address the organics fraction of waste. Thermal conversion of wastes does not discourage recycling nor negatively impact the environment as opposition groups claim. Those facts have been proven in this report with examples of quantitative data from peer reviewed assessments demonstrating that non-recyclable, non-compostable waste can re-enter the supply chain as needed energy and materials.

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