American Chemistry Council | Plastics-to-Fuel & Petrochemistry Alliance

Comparison of Plastics-to-Fuel and Petrochemistry Manufacturing Emissions to Common Manufacturing Emissions

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Plastics-to-Fuel and Petrochemistry (PTFP) facilities produce fuels and chemistry products from post-use plastics that are not traditionally recycled in commercial markets. PTFP technologies are a new generation of a manufacturing process known as pyrolysis.

PTFP technologies can complement the traditional recycling of post-use plastics and enable communities and businesses to divert greater quantities of valuable plastics from landfill. The production of fuels, chemical feedstocks, and monomers from post-use, non-recycled plastics can offset the need for some virgin material extraction and production. The U.S. Department of Energy's Argonne National Laboratory has determined that there are quantifiable environmental benefits to converting post-use, non-recycled plastics to fuels instead of sending these plastics to landfill.[1]

Pyrolysis: How does it work?

A PTFP facility first receives plastic feedstock that has been shredded, dried, and cleared of most non-plastic contamination. Next, this "post-processed" feedstock is heated in the absence of oxygen and halogen until it melts and the polymer molecules break down to form gaseous vapors. The condensable gases are converted to fuel and chemistry products while the non-condensable gases are collected separately and either combusted for process energy, or flared. Some of the products the technology can make include: fuels for transportation or boilers/furnaces, lubricants, waxes, or even feedstocks (such as naphtha or monomers) to produce new chemicals and plastics.

The ideal plastic resin feedstock depends on the intended end product. Generally speaking, resins that yield greater amounts of useful end products include high density polyethylene (HDPE), low density polyethylene (LDPE), linear low density polyethylene (LLDPE), polypropylene (PP), polystyrene (PS), and some engineered resins labeled as #7 Other via the Resin Identification Code (RIC). By contrast, polyethylene terephthalate (PET) has lower yields, and more importantly generally has strong traditional material-recycling markets. Polyvinyl chloride (PVC) also yields low amounts of marketable liquid hydrocarbon product because a large percentage of the weight of PVC is chlorine, which does not give rise to a combustible product such as a fuel. The presence of elements other than carbon, hydrogen, and oxygen is not generally desirable in the resultant pyrolysis products.

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1 "Life-cycle analysis of fuels from post-use, non-recycled plastics." Fuel. Volume 203, 1 September 2017. Pahola Thathiana Benavides, Pingping Sun, Jeongwoo Han, Jennifer B. Dunn, Michael Wang.

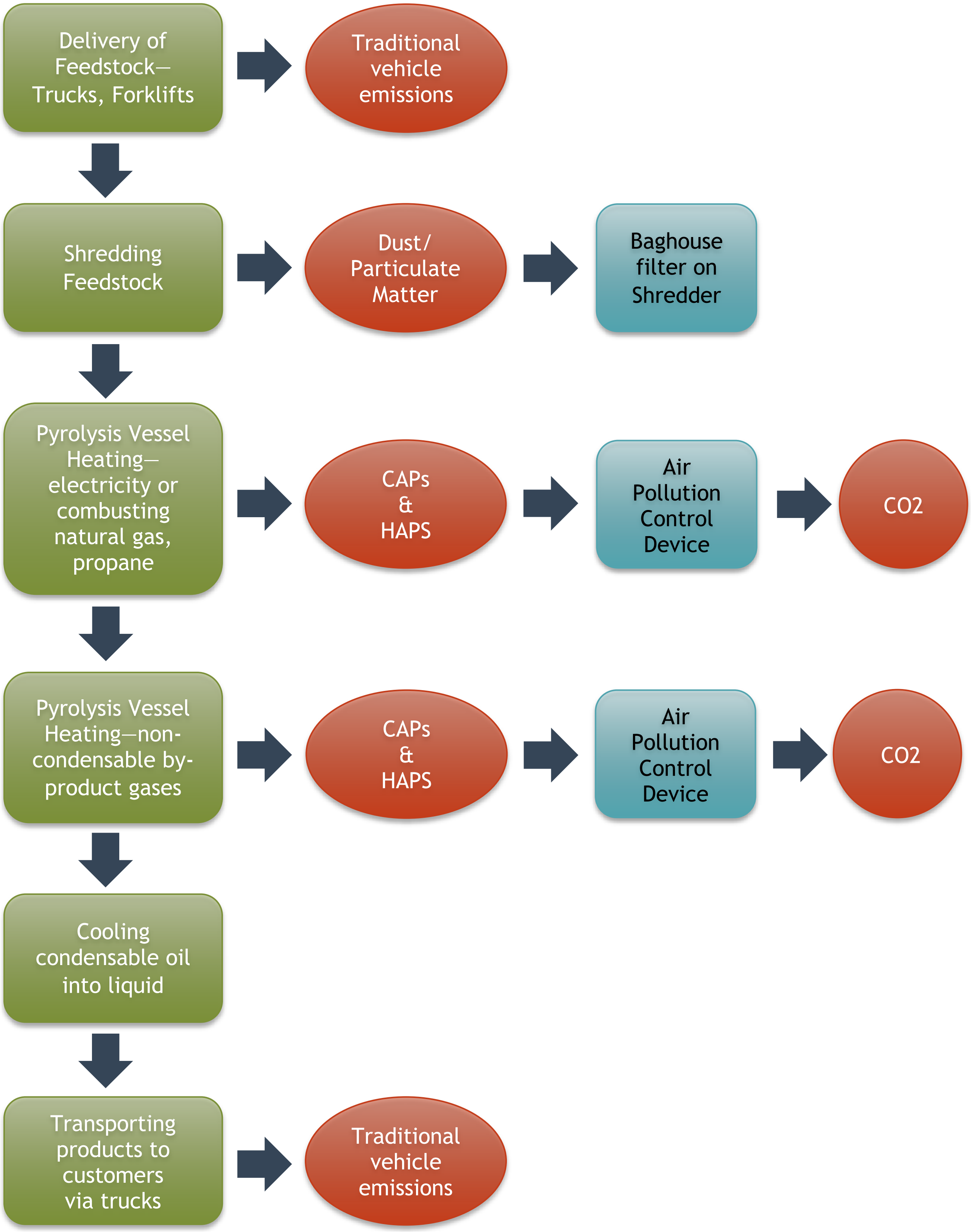
Plastics to Fuel: What are the primary steps and sources of PTFP emissions?

This paper explains what PTFP technology is and provides emissions data to help evaluate the safety of these operations. To put the data into context, we have provided emissions from several manufacturing industries. The data demonstrate that the emissions produced by PTFP technologies are lower when compared to many other industrial facilities found in communities across the country. This paper diagrams all the sources and types of emissions from a PTFP operation.

Importantly, pyrolysis is not the same as solid waste combustion. Instead, non-recycled plastics which have been sorted/separated three times (at the curb, at the recycling facility and once more to remove non-plastic contamination) are processed in a closed system that is heated in the absence of oxygen. The primary steps in the PTFP process include:

1. The site is visited by trucks delivering post-use plastic feedstocks. These materials are unloaded by a forklift that could be powered by gasoline, diesel, propane or electricity.
2. The feedstocks are shredded to reduce the size and densified in some cases. A filter collects the dust and contains it in a baghouse for disposal.
3. The pyrolysis vessels are sealed and starved of oxygen, then heated with electricity, natural gas, or propane. Because air pollution control devices are employed, the external emissions from heating pyrolysis vessels tend to be the same as a home stove or water heater on a per unit basis.
4. The newly formed vapors/gases are then cooled and condensed, and air pollution control devices are used to prevent additional emissions at this stage.
5. The non-condensable gases such as methane and hydrogen are generally co-fired with natural gas or propane to heat the vessels. This produces CO2 and water. Alternately, these gases are combusted with natural gas to destroy the emissions and produce CO2 and water. In the European Union, the non-condensable gases may not be co-fired to heat the vessels, so they are combusted directly.
6. After the gaseous vapors are condensed into the desired end products including crude oil, liquid fuels, fuel blendstocks or chemical feedstocks, the products are shipped offsite via rail, trucks, or barge that are most likely running on diesel fuel with emissions typical of that fuel.

Generalized Process Flow Diagram to Show Emission Sources and Types:



What PTFP emissions are regulated by the U.S. EPA?

There are both Federal and State programs designed to monitor emissions and protect communities' safety and well-being. The U.S. Environmental Protection Agency regulates both Criteria Air Pollutants (CAPs), and Hazardous Air Pollutants (HAPs). CAP emissions exceeding 100 tons per year are subject to federal regulation and require a Title V Permit. However, sources of any significant amount of CAP emissions must report the emission levels. In addition, CAPs may also be reportable under various state, regional, and other local air quality regulations (referred to as "local" regulations). Local jurisdictions (Departments of Environment, Air Quality Management Districts, etc.) are responsible for enforcement and often require more stringent reporting and limits on emissions than the EPA. CAPs are commonly found pollutants that are detrimental to human health, and include these 6 compounds:

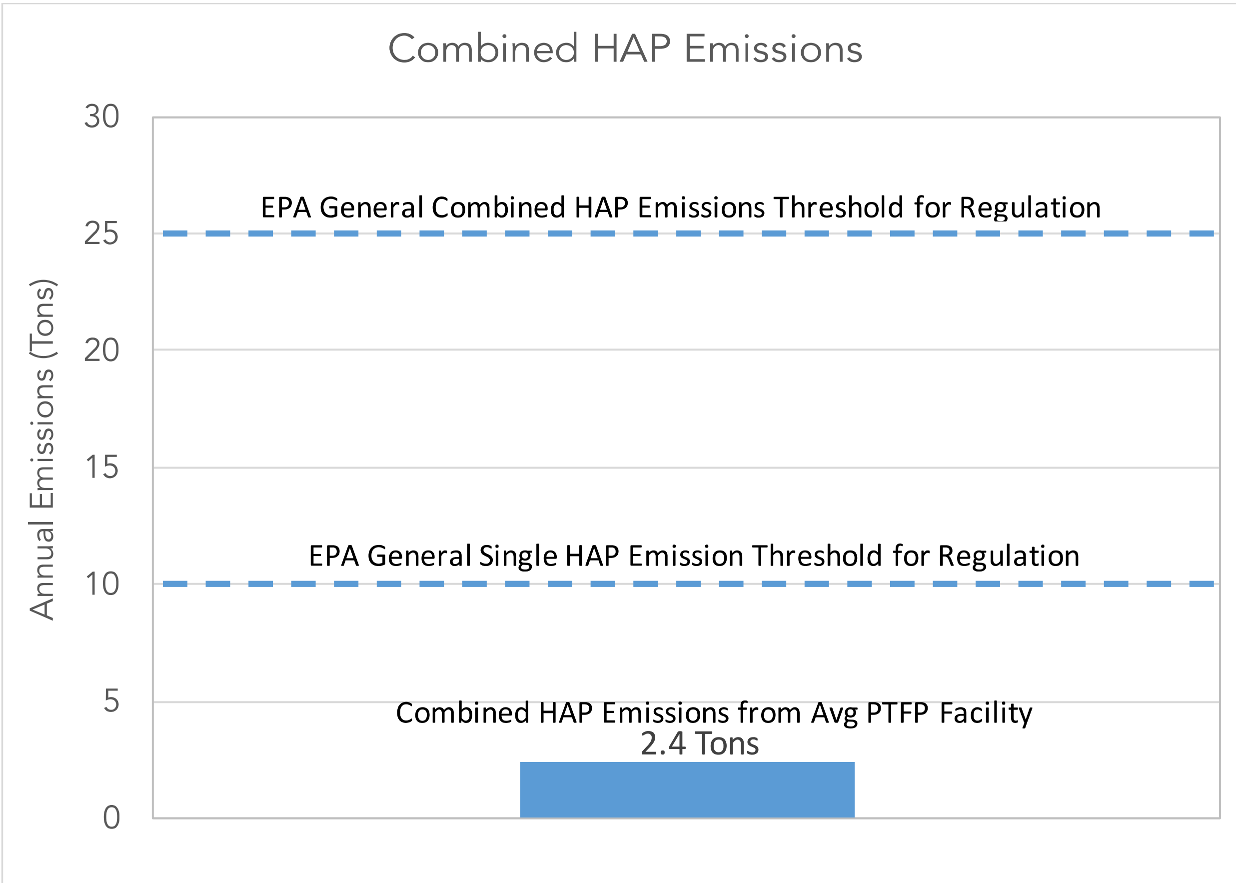
- Surface Ozone (O_3) / Volatile Organic Compounds (VOCs)
- Particulate Matter (PM)
- Sulfur Dioxide (SO_2)
- Nitrogen Dioxide (NO_2)
- Carbon Monoxide (CO)
- Lead (Pb)

The EPA also lists and regulates 187 HAPs under the Clean Air Act. HAPs are toxic air pollutants that cause or may cause serious harm to human and environment health. The EPA regulates these pollutants from general industrial sources at levels of 10 tons per individual HAP and 25 tons of combined HAPs per 12-month period. The following is a list of the primary contributing HAPs that could be produced by PTFP facilities:

1. Benzene
2. Toluene
3. Ethyl benzene
4. Xylenes

Combined HAP Emissions

Permitting data indicates that PTFP facilities are expected to create very few HAP emissions and are likely to be well below federal permitting requirements. In fact, at some PTFP facilities with lower scales of production, very little to no HAP emissions are expected.



What are the emissions of PTFP facilities and what are they comparable to?

A PTFP facility generates CAPs, and this paper provides context for these emissions by benchmarking them to other common manufacturing activities. For this paper we have modeled the “Typical PTFP Facility” as one that processes 15,000 tons per year of inbound plastics. This “Typical Facility” represents an average size for facilities that provided data for this paper. A typical PTFP facility is not required to have a Title V Permit under the Clean Air Act because its emissions would fall below the emissions levels which trigger need for a permit.

A typical PTFP facility’s CAP emissions as a group are not comparable to any single industry. However, several of its individual CAP emissions are comparable to those of numerous specific, well-regulated facilities that are required to report to the EPA under the Clean Air Act.

VOC (Volatile Organic Compounds) and PM_{10} (Particulate Matter under 10 microns) emissions from a typical PTFP facility are roughly comparable to those from smaller than average Food and Snack Processing Plants;

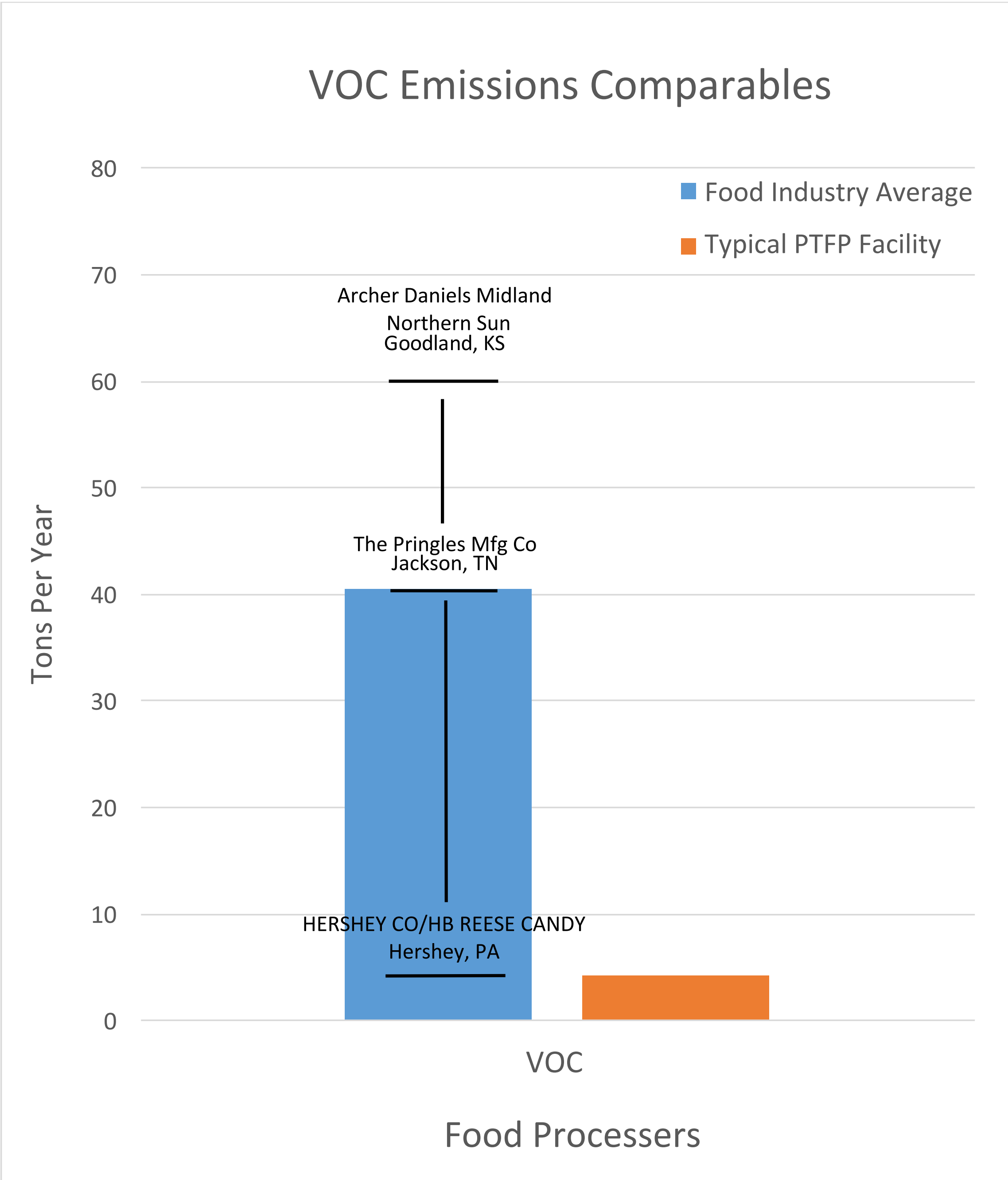
SO_2 (Sulfur Dioxide) emissions are roughly comparable those from smaller than average Institutions (Hospitals, Universities, and Prisons);

NO_2 (Nitrogen dioxide) emissions are roughly comparable to those from average Institutions (Hospitals, Universities, and Prisons); and,

CO (Carbon Monoxide) emissions are comparable to those from average Auto Manufacturing Operations.

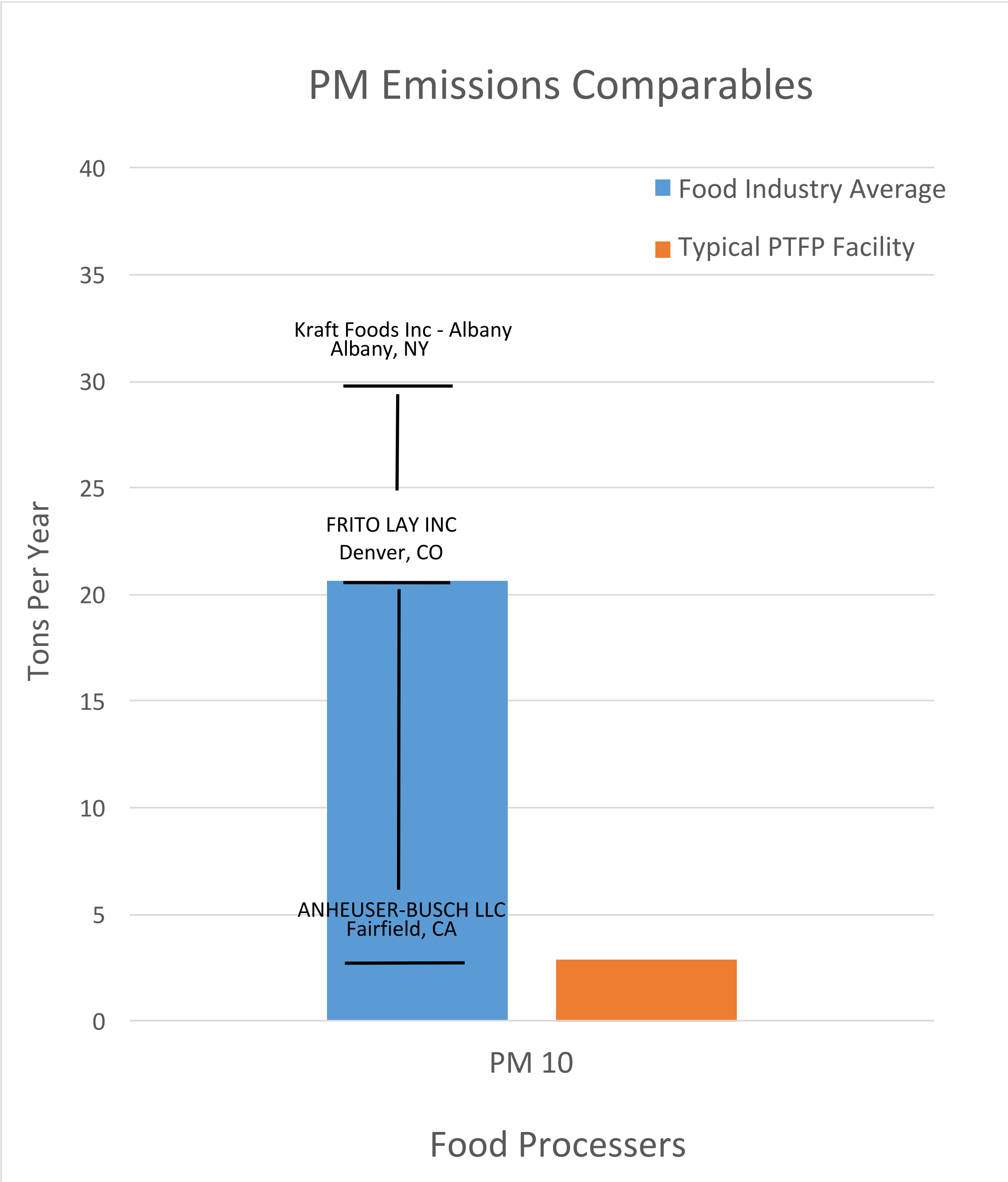
While Lead is also a CAP, there are no measurable Lead emissions from PTFP facilities and so it is omitted from this paper.

Volatile Organic Compounds (VOCs)



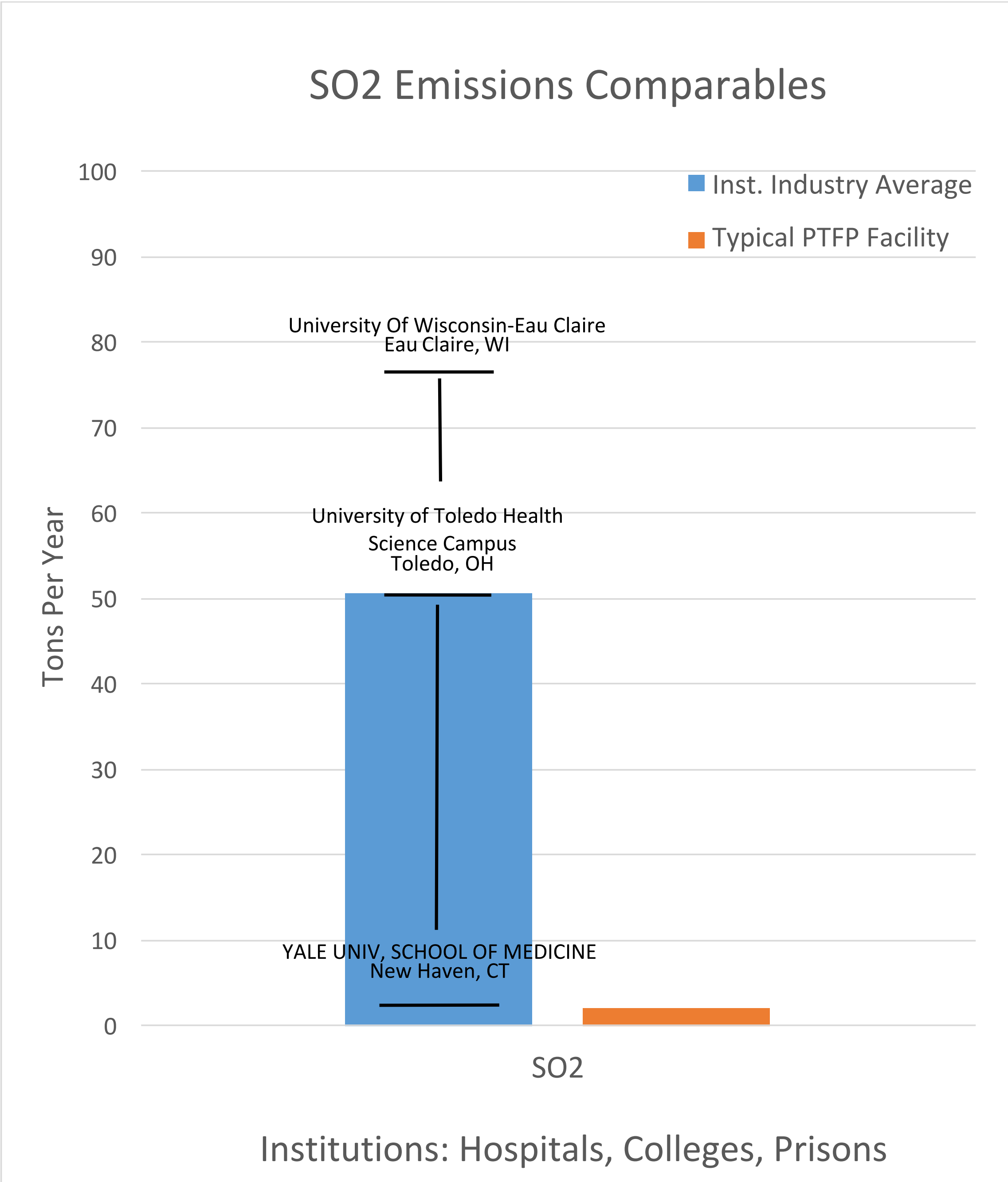
The Typical PTFP Facility will emit less than 5 tons of VOCs annually. For comparison, the average reporting food processing facility in the U.S. (excluding those facilities with less than 1/10 of a ton of emissions) reports 40 tons of VOCs emitted annually. For comparison, the Typical PTFP Facility emits roughly as much as the Hershey/HB Reese candy production facility in Hershey, PA.

Particulate Matter, under 10 microns (PM_{10})



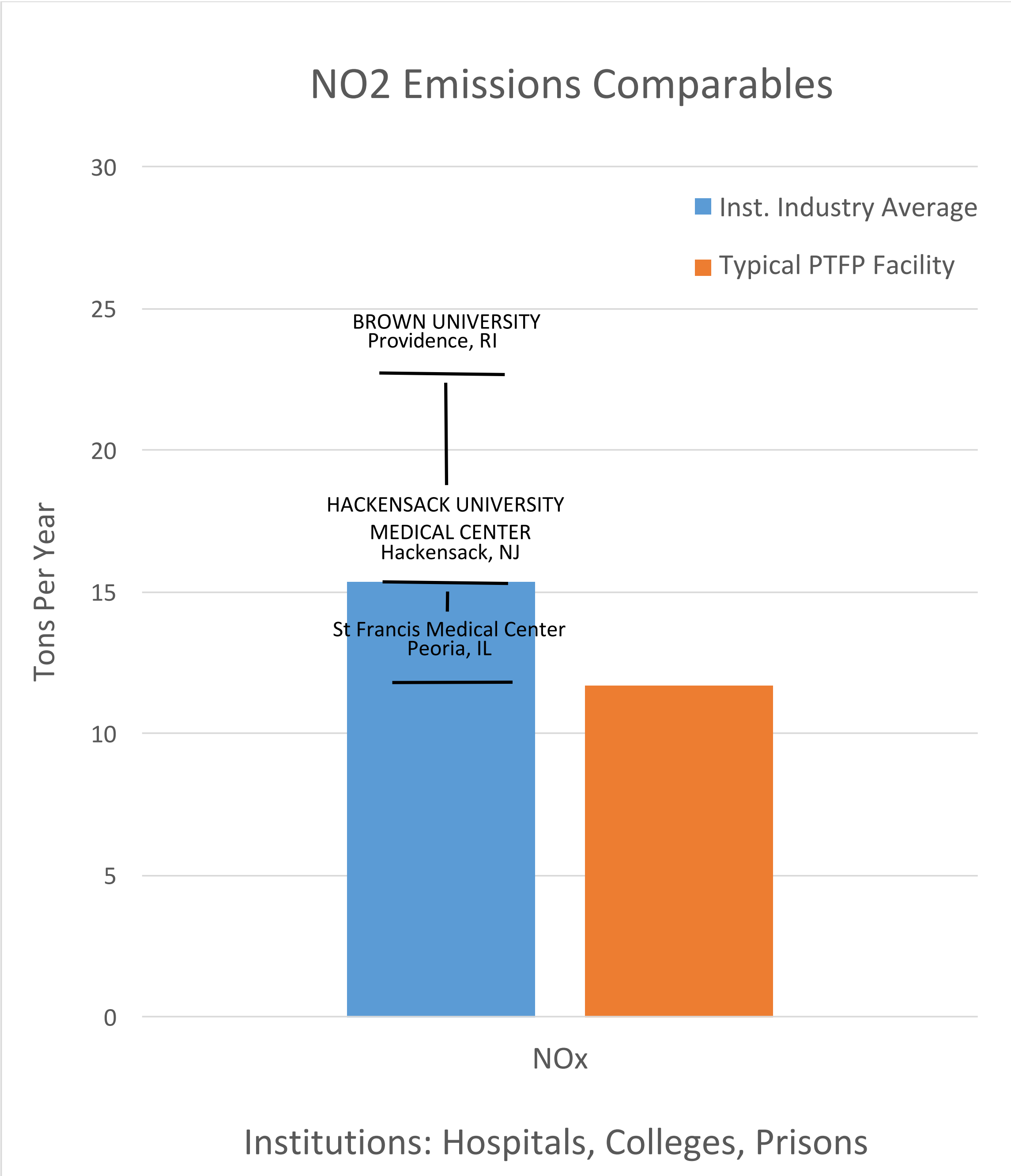
The Typical PTFP Facility will emit less than 5 tons of PM_{10} annually. For comparison, the average reporting food processing facility in the U.S. (excluding those facilities with less than 1/10 of a ton of emissions) reports 20 tons of PM_{10} emitted annually. For comparison, the Typical PTFP Facility emits roughly as much as the Anheuser-Busch Brewery in Fairfield, CA.

Sulfur Dioxide (SO_2)



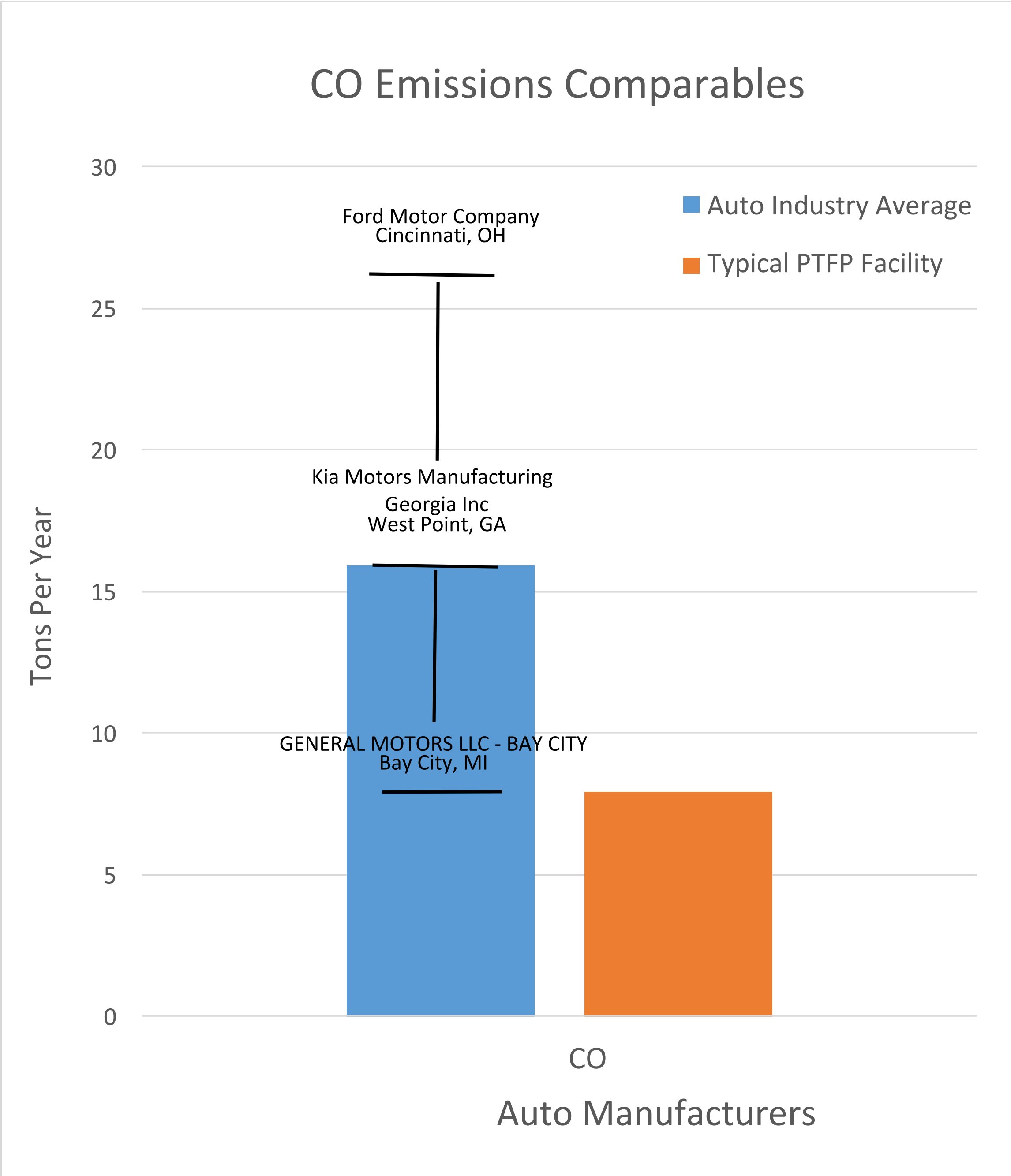
The Typical PTFP Facility will emit less than 5 tons of SO_2 annually. For comparison, the average reporting institutional campus in the U.S. (excluding those facilities with less than 1/10 of a ton of emissions) reports 50 tons of SO_2 emitted annually. These emissions typically come from an onsite power plant or generator. For comparison, the Typical PTFP facility emits roughly as much as the 15 megawatt combined heat & power (CHP) power plant providing energy to the Yale School of Medicine.

Nitrogen Oxides (including NO_2)



The Typical PTFP Facility will emit less than 12 tons of NO_2 annually. For comparison, the average reporting institutional campus in the U.S. (excluding those facilities with less than 1/10 of a ton of emissions) reports 15 tons of NO_2 emitted annually. These emissions typically come from an onsite power plant or generator. For comparison, the Typical PTFP Facility emits roughly as much as the power plant providing energy to the St. Francis Medical Center in Peoria, IL.

Carbon Monoxide (CO)



The Typical PTFP Facility will emit less than 10 tons of CO annually. For comparison, the average reporting Auto Manufacturer/Assembler in the U.S. (excluding those facilities with less than 1/10 of a ton of emissions) reports 15 tons of CO emitted annually. For comparison, the Typical PTFP Facility emits roughly as much as the General Motors (GM) transmission and engine parts manufacturing plant in Bay City, Michigan.

Why Dioxin is not a concern for PTFP facilities

Where do dioxins come from?
For forty years, it has been known that poorly controlled combustion of waste gives rise to dioxins, furans, and other products of incomplete combustion. Most dioxins found in the environment today are man-made and were created before 1990. Historically, incinerators, the manufacture of certain herbicides, and pulp and paper bleaching were among the largest industrial sources of dioxins.

Since then, regulation and subsequent technical advances have led to drastic decreases in dioxin emissions. Between 1987 and 2000, for example, dioxin emissions declined 90% in the U.S.[2] As dioxin emissions from industry declined, unregulated sources such as forest fires, backyard barrel burning of garbage and residential wood burning have risen in significance as contributors to dioxin emissions. In fact, backyard burning of waste is currently the largest source of dioxins at 35% of the U.S. total.

For more information, please see dioxinfacts.org and World Health Organization: http://www.who.int/ipcs/assessment/public_health/dioxins/en/

How do Plastics-to-Fuel and Petrochemistry technologies prevent dioxin formation?
Proper operation of a PTFP facility will not result in the production of dioxins primarily because the material is heated in a closed, oxygen-deprived environment that causes a thermo-chemical reaction *that is not combustion*. However, if the technologies are operated incorrectly – in a way that damages the equipment and makes the products unsaleable, then it's possible to produce dioxins. Given that PTFP technology is designed to recover valuable products, not to destroy itself and produce liabilities, these technologies are designed and operated to prevent dioxins.

Based on operating and lab data from 6 companies, dioxins are not produced during pyrolysis because:

- There is no atmospheric oxygen or halogen in the pyrolysis chamber
- The products of pyrolysis spend virtually no time at the dioxin formation temperature
- Vapors resulting from pyrolysis are combusted at temperatures well above the total destruction temperature of dioxins and furans

2 U.S. Environmental Protection Agency (EPA), 2006. An inventory of sources and environmental releases of dioxin-like compounds in the United States for the years 1987, 1995, and 2000. National Center for Environmental Assessment.

Detailed Practices for dioxin prevention in operations of PTFP facilities.

Feedstock Controls:

1. **Specifications Enforced with Scanners and Contractual Penalties —** Plant operators sort the inbound material to ensure a feedstock predominantly composed of carbon and hydrogen. Chlorinated plastics are generally excluded from PTFP technologies because those resins have very low yields of marketable petroleum products and can produce acidic byproducts that corrode the equipment and cause the marketable products to fail to meet strict customer specifications. For these reasons, feedstock specifications are strictly enforced using optical scanners and hand held scanners to determine the makeup of the inbound plastic materials. Further, contracts with the feedstock provider often require the specification to be met or they are subject to fines and penalties from both the PTFP operating companies and purchasers of the final product.
2. **Additional Quality Controls** — Many operators randomly spot check the purveyors of the feedstocks at the source (usually plastics recyclers). Finally, some of the technology operators pay their staff a bounty on off-spec material and reward them for reducing contamination.

Vessel Controls to Ensure Pyrolysis, not Combustion:
The vessels where the primary thermal reaction occurs is flushed with nitrogen to eliminate oxygen or halogen and not only prevent combustion, but also dioxin and furan formation.

Temperature Controls:
Pyrolyzing plastics without oxygen does not create dioxins and is different than combustion in incinerators. Pyrolyzing plastics yields new gases that can be condensed into fuels and non-condensable gases that may contain chlorine. The cooling of these gases or the destruction of these gases is controlled to prevent dioxin formation.

1. **Controlled Cooling** — The condensable gases are rapidly cooled to prevent the formation of dioxins that could occur if they were to sit for an extended period in the temperature range of 200°C – 400°C (392°F – 752°F).
2. **Controlled Destruction** — The non-condensable gases are destroyed through a high temperature destruction device that uses methane to ensure complete combustion at approximately 600°C – 800°C (1,202°F – 1,472°F)[3]. Similarly, when the non-condensable gases are used instead for thermal energy to heat the pyrolytic vessels, they are also co-fired with methane at the same temperatures to prevent dioxin formation.

[3] Aurell, J. and S. Marklund. 2009. Effects of Varying Combustion Conditions on PCDD/F Emissions and Formation During MSW Incineration.

Conclusion

The data illustrate that Plastics-to-Fuel and Petrochemistry technologies are expected to have air emissions that are well below regulated levels, below well-known industries in every category of emissions, or in most cases both. These technologies offer a unique way to recover mass, energy and polymer feedstocks from plastics that are not recycled in commercial markets and are currently being landfilled.

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Appendix – Methodology

Normalizing Emissions Data

Data from permits have been scaled to incoming feedstock (which is reported in permitting applications). This allows for a calculation to normalize emissions per ton of incoming feedstock. Further, we set the capacity of the facilities at a near average capacity of 15,000 tons of inbound feedstock per year.

Conservative Overestimation

At the time of this paper, only a few of the PTFP facilities have commercial run data. The others have data from bench trials. Good Company conservatively estimated scaled up bench trials and commercial run data. Therefore, PTFP facility emissions were overestimated by using publicly available permit limits approved by local regulators. Permit limits are approved by local regulators based on bench trial (lab) data, test runs of operating equipment and required air pollution control devices. These limits represent the top end of possible emissions, which may lead to an overstatement of PTFP facility emissions.

Industry Emissions Data

Industry emissions data are sourced from the EPA's 2011 National Emissions Inventory—the most recent at the time of this analysis. EPA's inventory is a database made up of an aggregation of locally and federally reported CAP emissions. Any facility required to report any single CAP emissions at either level is included in this database. This leads to some facilities having near zero emissions of a single CAP because that facility is required to report substantial emissions in another CAP (and therefore all its CAP emissions). Additionally, reporting thresholds (bottom of permit range) vary between local regulators, leading to possible inclusions of some facilities and exclusions of others, even if they have similar emissions profiles (this occurs when emissions fall beneath federal Title V permitting).

The average emissions per industry reported in this paper is a straight average of emissions excluding facilities that reported under $1/10^{th}$ of a ton of CAP emissions in that category. This exclusion is an attempt to remove "incidental" emissions that are included in the database as described in the above paragraph.

Disclaimer

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