



A PET Circular Economy for The City of Phoenix

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Abstract:

The City of Phoenix is interested in bringing a plastic processing facility to the Phoenix metro area. A facility could potentially to increase the diversion rates of recyclables, allow for more efficient use of locally reclaimed material and bring new jobs to the Phoenix metropolitan economy. Contrary to the classic “put it in the bin, we’ll take care of it” attitude presented by large recyclers such as Waste Management and Republic Services, recycling economics are complex; often both a beacon of technological advancement and a lagger with regard to spot-market capabilities. Based on interviews with elite stakeholders and industry research, this mixed method paper will examine the current PET plastic recycling market and the potential for Phoenix to increase its circular manufacturing of plastic. The final analysis will culminate in a proposed set of recommendations that could help Phoenix achieve its long-term waste diversion goals.

1. Introduction:

In the most recent waste audit by the Environmental Protection Agency (EPA), the agency found approximately 262 million tons of municipal solid waste was generated in the United States. Of this total, more than 91 million tons of material was recycled and composted while 34 million tons of material was combusted for energy recovery. The remaining 137 million tons of waste was directed to landfill (EPA, 2015, p.2). In 2016, the EPA found that for every 89 million tons of municipal recycled waste, the United States yearly carbon dioxide output was reduced by 181 million metric tons (p.3). At that time, the focus of the EPA was to encourage sustainable materials management, referring to the “use and reuse of materials in the most productive and sustainable way across their entire life cycle (EPA, 2017).” Since 2016, municipal governments, corporations, and consumers still care about reducing waste, but the global recycling market has entered a period of radical change.

Historically, municipalities and corporations in the United States have depended on China’s low-freight transportation cost, relaxed environmental restrictions, and cheap manual labor to achieve their recycling goals (Allan Company Representative. Personal Phone Interview. Sep. 1, 2018). For the United States alone, this meant up to 4,000 shipping containers—or nearly 160,000,000 pounds of plastic and paper—had been landing on China’s shores for processing every day (Carring, 2018). At the beginning of 2017, however, China shocked the world with the final stage of an antipollution campaign titled “National Sword,” effectively closing China’s recycling market to the world in a short period of three years. While there had been speculation that China could not pull it off, China has stayed true to its word, shutting down factories and focusing on processing only waste within its borders (Allan Company Representative. Personal Phone

Interview. Sep. 1, 2018). Not only has this left the United States scrambling for solutions but tens of millions of tons of recyclables have been piling up globally (Couronne, 2018).

Academic, governmental, and industrial studies suggest the problem with surplus U.S. recyclable waste is already urgent and getting worse. One large scale “solution” available to a majority of U.S. cities is to dump the material in American landfills (Albeck-Ripka, 2018). Not only has this measure already increased the amount of greenhouse emissions coming from landfills in the United States but the problem is further compounded when waste enters a landfill. When recyclables enter the landfill, it is nearly impossible to recover the material in the future after exposed to landfill contamination (Albeck-Ripka, 2018). This shortsighted scheme will prevent the United States from decreasing the amount of its emissions and landfill emissions will continue to affect ground water and air quality for communities near landfill sites (Gies, 2018).

1.1 Local Impact

The City of Phoenix, Arizona (Phoenix) has problems with its waste stream, typical of any other U.S. city. Phoenix’s diversion rate for recyclables is around 33 percent (The City of Phoenix, 2018), the contamination rates for the material is high, and worse yet, the city struggles to find a solution other than landfill. However, unlike many cities in the United States, Phoenix *owns* the recyclable material that it collects. Owning the commodity may prove to be an opportunity to solve its recycling woes because Phoenix is able to sell its plastics and profit from the recycled material stream. This opportunity is not risk free, it should be noted, because as the value of the plastics fluctuates, the city will receive revenue consistent with the market values. As of 2018, for example, the price per pound of plastic is only a couple cents higher than the all-time commodity low, meaning tighter operating margins for plastic collection and sorting. Because there is no single public or private market that can trade plastic, a default market has been

confederated from a range of large recycling institutions to independent brokers to sell recycled material through pre-existing relationships and a “highest bidder” scenario (Anonymous. Defunct Plastic Brokerage Firm. Personal Phone Interview Sep. 19, 2018).

Selling plastic commodities through pre-existing relationships removes an element of risk China previously assumed. Before the National Sword policy, China would accept material from anyone, a force that led to unscrupulous actors taking advantage of the Chinese market and sending poor quality materials the Chinese could not return (Allan Company Representative. Personal Phone Interview. Sep. 1, 2018). In Phoenix, when a bale of PET bottles is ready, it is advantageous to sell material to preferred buyers as far away as Georgia or the Carolinas (Unifi, Inc. Representative. Personal Phone Interview. May 12, 2018). Even though the distance adds both a financial and environmental cost, Phoenix may value a consistent buyer just as much as the buyer may value consistently high-quality material. However, it is this type of pre-existing relationship that inhibits competitive growth in the market and creates entry barriers for any business or government involved in selling recovered plastic materials because the market is built on who you know and not what you have to sell (Erema Plastic Recycling Systems Representative. Personal Phone Interview #1. Oct. 16, 2018).

Additionally, the current system for buying and selling plastic recyclables does not incentivize the *tracking* of the material. Cross-country transactions are not uncommon and without a central exchange, transportation efficiency can be lost. If Phoenix is sending material to a buyer in Ohio, and a different vendor is sending material from Kansas to Utah, these shipments could potentially save environmental and financial costs through a material exchange agreement. A future plastic economy should be able to track materials transparently and utilize the most effective economic and environmental cost of plastic bought and sold.

1.2 Circular Economic Solution

Aside from attempting to reduce overall societal consumption, the prevailing industry-based solution to sustainability is to increase national circular economic capabilities (Wood, 2018). Traditionally, circular economy is defined as an industrial economy where waste is minimized or nullified completely, and therefore is restorative and regenerative by intention (Ellen Macarthur Foundation, 2017). Improving manufacturers' abilities to take advantage of waste products will allow the material to reenter the value chain of multiple stakeholders instead of the landfills thereby saving monetary capital, natural capital, and reducing manufacturing related emissions around the world as part of a circular economy.

In the context of waste and waste stream resources, circular economy flows are self-sustaining and comprise a closed loop resource stream that reuses and recycles so that waste is minimized. The greatest barrier for circular economic design is the system's ability to reclaim material. Circular economic thinking assumes there is a sufficient supply of recycle-ready plastic to be processed and unfortunately this may be a false assumption.

Judging by the previously mentioned amounts of recyclable material being forced into U.S. landfills, domestic systems of resource recovery are under duress. The main problem is not limited to plastic's inability to be reprocessed or the American consumer's addiction to single-use plastic applications which account for approximately 50 percent of packaging, and disposable consumer items (Hopewell, Dvorak & Kosior, 2009, p. 2115). Ultimately, the greatest strain on the resource recovery system may be linked to the plastics market inability to scale in rural areas and growth in capacity from consumer support (Stanislaus, 2018). Without increase scaling, it may be unlikely to meet the increased of supply and demand from manufactures and brands willing to used recycled material.

However, a “substantial amount of work in public policy, business ethics and consumer behavior reveals that public authorities can influence ethical behavior among consumers (Cherrier, 2006, p. 515).” Indeed, a coordinated effort between government, industry, and scholars focused specifically on modifying consumer behavior with regard to plastics, is commonplace. In January 2011, in Malaysia, for example, a “No Plastic Bag Campaign Day” was launched by the nation’s Ministry of Domestic Trade, Cooperative and Consumerism (MDTCC) with the intention of reducing “the excessive consumption of plastic bags and saving the environment. The nationwide campaign engaged selected super/hypermarkets, major retailers and major shopping malls every Saturday at customer-end level (Zen, Ahamad, & Omar, 2013, p. 1260).” Even in the United States, states that are able to pass legislation that assign a reclaim value to plastic bottles through a “bottle bill” can see a dramatic increase in reclaimed recyclable material post-consumer use (Karidis, 2018).

Before a further discussion about potential solutions regarding plastics, recycling and market forces, it is important first to clarify important terms and concepts with regard to sustainable solutions and the people who will be determining them.

1.3 Plastic:

A plastic can be defined by any numerous organic, synthetic or processed material that is mostly a thermoplastic or thermosetting polymer of high molecular weight and that can be made into object, film, or filament (Merriam Webster, 2018). Plastics can be divided into seven categories and ranging in different industrial and consumer applications. For the purposes of discussion, the plastics recycling market will be examined with respect to Polyethylene terephthalate (PET). As one of two most commonly recycled plastics on the market, PET makes up a majority

of the world's bottle packaging and has maintained a value to manufacturers. In 1988, the Society of the Plastics Industry (SPI) established the classification system to allow consumers and recyclers to identify and sort different types of plastic according to their market value. Manufacturers place an SPI code, or number, on each plastic product, usually molded into the bottom of the item or container. This guide provides a basic outline of the different plastic types associated with each code number. In reverse order:

7. Category 7 is a catch-all category that is meant to designate miscellaneous types of plastic not defined by the other six codes as well as types of plastics are difficult to recycle. Examples of consumer products include but are not limited to plastics found in car parts, compact discs or medical devices.

6. Polystyrene (PS) is commonly recycled but is labor intensive. This category includes items such as disposable coffee cups, plastic food boxes, plastic cutlery and packing foam.

5. Polypropylene (PP) is occasionally recycled. PP is strong and can usually withstand higher temperatures. It is used to make margarine containers, yogurt pots, syrup bottles, prescription bottles.

4. Low-Density Polyethylene (LDPE) is difficult to recycle but is a versatile plastic that tends to be both durable and flexible. Items such as cling-film, sandwich bags, squeezable bottles, and plastic grocery bags are made from LDPE.

3. Polyvinyl Chloride (PVC) is most commonly recycled through industrial waste streams. PVC is used for many kinds of industrial uses but is most commonly found in a variation of plumbing applications such as piping.

2. High-Density Polyethylene (HDPE) is considered the most commonly used and recycled plastic. HDPE products are very safe and are not known to transmit any chemicals into

foods or drinks and items made from this plastic include containers for milk, orange juice, shampoos and conditioners, soap bottles, detergents, and bleaches.

1. Polyethylene Terephthalate (PET) is a highly versatile plastic and is commonly recycled. PET(E) plastic is used to make many common household items like beverage bottles, medicine jars, rope, clothing and carpet fiber.

Due to its versatility, PET has become one the most widely produced synthetic polymers in the world, used in almost every consumer product. PET is used as raw material in the production of synthetic fibers for carpet, in the manufacturing of plastic bottles, outdoor/active/fashion wear as well as food containers. Experts estimated in 2017, that PET plastic bottles alone account for around one million plastic bottles consumed every minute globally (Nace, 2017).

1.4 Recycling:

Recycling, is a broad term that includes a series of steps where used material is recovered from the consumer, turned back into a commodity and manufactured into a good. Many countries achieve this outcome through different “take-back schemes” but in the United States, the leading system is known colloquially as “single stream collection.” For most municipalities across the United States, this process begins with households and consumers placing recyclable materials in a single collection bin. For typical single-family homes, the final result is taking the recyclable materials out to the curbside while in multi-family units or larger commercial facilities, the materials will be aggregated to central recycling storage receptacles. Usually once a week, large collection vehicles will take the discarded plastic, paper, glass and metals to a material recovery facility (MRF) to be sorted by different waste streams. The most valued of these waste streams are PET, aluminum cans, HDPE, and mixed paper.

Once sorted, bales weighing roughly 1,200 pounds apiece are sold through a brokering process on the spot market to the highest bidder. There is no national commodity value associated with post-consumer PET plastic per pound. The values range from region to region and can vary between different brokering relationships. In November of 2018, a bale of plastic bottles fluctuated values between 15-20 cents per pound (Plastic Recycling Corporation of California, 2018). Values depends on contamination levels, source of the bale, distance needed to travel and any pre-arranged pricing agreements (Allan Company Representative. Personal Phone Interview. Sep. 1, 2018). The bales make their way around the country to their next destination, a toll processor.

Toll processing is an industry term for any manufacturer that accepts a material input and processes it into a higher value output ready for additional manufacturing. In the case of a PET bottle bale, a PET toll processor will likely turn a plastic bottle into a plastic flake or pellet ready for industry reuse. Re-processing materials has been part of U.S. history since the widespread use of plastic in 1973. In the early days, small-scale toll processors collected waste materials, melted the plastic and reprocessed the material using rudimentary toll-processing methods in garages or small-scale facilities (The Plastics Group of America Representative. Personal Phone Interview. Aug. 16, 2018). Now, the field is regulated, automated and with many safety and environmental measures taken in to account. PET toll processing includes the following steps:

- **Size Reduction:** PET bottles are pre-washed as they enter a large grinder. Grinding the bottles not only reduces the bottles to small plastic shreds but also begins the crucial process of separating the PET plastic of the bottle from the HDPE plastic bottle cap and neck rings, LDPE labels and glue.

- **Sorting:** Facilities can employ two methods to ensure material separation. Automated optical sorting machines kick out large pieces of HDPE from the PET loads while float tank separation sorts the HDPE that floats while PET sinks below the surface.
- **Washing:** Once the PET stream has been de-contaminated of HDPE, the PET must be washed of any additional contamination including the label, glue and beverage residue.
- **Size Reduction:** An additional size reduction may be necessary to create a more uniform size of PET flake, ready for an end market.

Depending on customer preferences, some toll processors will produce a market ready flake or they will process through additional steps to add chemical consistency and fiber uniformity to the end product. This happens through the compounding and pelletizing process.

- **Compounding:** When the washed flake enters this stage, the resin is heated to melting temperature. Some toll processors specialize in resin compounding which involves adding specific chemicals to the newly melted mixture to strengthen the plastic, giving the plastic custom manufacturing traits and ultimately creating a high value, chemically uniform product.
- **Pelletizing:** The melted resin is then pushed through an extruder to create identical pellets ready for industrial purposes that can match any virgin material feedstock.

1.5 Recycled Plastic Economics:

According to the latest report from The Association of Plastic Recyclers, 2016, the total pounds of PET bottles collected for recycling reached 1.753 billion pounds or 28.4% of the total volume in the United States (The Association of Plastic Recyclers, 2016, p. 2). The report also noted a 44 million-pound decrease since 2015, citing a particularly difficult market for recycled

plastics. The recycled plastic market is directly tied to the cost of petroleum. In 2016, virgin PET prices were driven down by a series of developments such as domestic overcapacity, flattening of demand, pressure from lower cost imports and plummeting raw material prices (Keel, 2017). In turn, this impacted the price of virgin plastics creating a competitive market for post-consumer, recycled PET. “Post-consumer plastic bottle recycling industry experienced a difficult year in 2016 with lower bale prices for bale sellers and lower competing virgin polymer prices for reclaimers. Margins were tight both for bale sellers and for plastic bottle reclaimers (The Association of Plastic Recyclers, 2016, p. 2).” In 2018, the values of recycle-ready PET and virgin material have stabilized. According to Plastic News, a leading source for plastic commodity pricing, recycled PET flake is valued at 44 to 56 cents per pound while virgin resin is valued around 85 to 96 cents per pound. IHS Markit, a London based market information firm, analyzed the difference between the two commodity materials and “revealed a manufacturer indifference point of 50 cents per pound. This means that pure raw material economics will discourage substitution of virgin by recycled resin in the short-term (Keel, 2017).” Tison Keel, an IHS Markit representative, recognized that brands may be more willing to substitute recycled PET for the consumer marketing advantages if the quality *and* quantity could meet manufacturing demand but Keel also conceded this relationship could change if oil prices were to drop in 2019.

Aside from consistent market pressure from virgin plastic, consumer participation is also a significant barrier to the success of plastic bottle recycling. Many consumers continue to be unaware of the significant usefulness, demand, and value of recycled plastic. Municipalities need to understand that they can benefit from the sale of bales of bottles, including revenue sharing that covers costs of collection and potentially helps fund programs city and state wide (The Association of Plastic Recyclers, 2016, p. 10).

Using recycled plastics has become part of the standard operations of many companies. Industry giants like Nestle, Nike, Adidas, Coca Cola, Pepsi, etc., have recently signed an international agreement to use only recycled plastics for their processes by 2025-2030. Each company had faced pressure from advocacy groups and an increasingly more environmentally minded consumer base. Ecover and CarbonLite have become leaders in the use of recycled plastic for bottle packaging, while Unifi, Inc. produces recycled PET thread used by a variety of brands including Nike, North Face, Under Armor and Adidas.

1.6 Previous Phoenix Based Research

In November of 2017, a comprehensive report was published by the L. William Seidman Institute on behalf of the Rob and Melanie Walton Sustainability Solutions Initiatives using data from 2014 gathered for a waste characterization of Phoenix by Cascadia Consulting Group. The 2017 report titled *The Circular Economy: Quantifying the Gross Maximum Economic Contribution of Materials in the City of Phoenix Waste Stream* found that “one of the quickest potential opportunities for the city of Phoenix from a recycled plastic perspective could be to focus on the processing of post-consumer PET into flakes or pellets, for sale as a feedstock in manufacturing (Resource Innovation and Solutions Network, 2017).” The study concluded that the Phoenix already recycles 4,859.8 tons of post-consumer PET each year and could potentially divert an additional 4,245 tons from its municipal waste stream to increase its processing capabilities (Resource Innovation and Solutions Network, 2017). The report posited that the approximately 9,000 tons of post-consumer PET would be a sufficient supply for a facility similar to a facility operating in Oregon, called ORPET, which has not only remained operational since 2010 but has received praise for its ability to handle over 7,500 tons of recycled PET a year (Thomas, 2012).

Even with the RISN report, a major question remains, however. Are there previously undocumented factors that have not allowed the Phoenix to support a PET processing plant? Any sustainable solution must narrow the margin of error for any initiatives regarding the circular manufacturing of plastic. The rest of this paper will focus on addressing previously understudied aspects of PET processing with the aim of creating a set of proposed recommendations which could help Phoenix achieve its long-term waste diversion goals.

2. Method for Research:

Beginning in June of 2018, approximately 100 plastic recycling industry leaders were canvassed with the intent of engaging them in qualitative and quantitative research regarding their inside knowledge of recycling operational practices and tradecraft. Because of a paucity of primary information with regard to the opinions and outlooks of frontline recycling managers in scholarly literature, this researcher sought direct industry insider knowledge from this under-appreciated primary resource. Of the approximately 100 contacted, 25 chose to respond, a figure which represents a 25 percent return rate. Through a series of phone calls and emails, these industry leaders were willing to reveal the latest boots-on-the-ground challenges and future opportunities in recycling, reprocessing, brokering, and waste management policy.

The interview style followed a semi-structured and unified format between all the participants where a series of roughly thirty questions were asked in a conversational interview. Given the range of occupations for the participants, questions were sometimes tailored to the industry of a subject. Furthermore, informal, follow-up supplemental questions were asked in order to gain more insight into specific expertise or areas of interest when appropriate. For the project, each interview not only brought new insight but also additional questions which may have been previously unconsidered or not even known to be asked (see - Appendix 1).

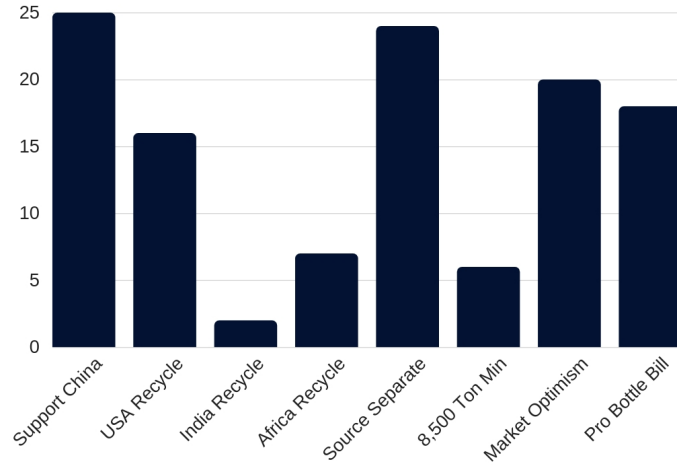
The collection of firsthand information rarely comes without challenges. Most questions were aimed at gaining qualitative, operational insight within certain recycling industries while a subset of questions might require private companies to reveal proprietary data such as facility capital expenditure costs, annual operational costs, volumetric flows of input, and output material and client rosters. Most stakeholders willingly gave complete answers, but a few were unwilling to share details liberally. Data points and opinions were given most freely under a guarantee of anonymity. Those that requested anonymity are cited by their position within the industry, location, and time and date of the interview (see - Appendix 2).

In a competitive market place, understandably privately-owned institutions are often weary of sharing their “secret sauce.” One stakeholder who was not included among the participants, even went as far as to comment he was unwilling to share any amount of information, at any time, given the amount of competition within the city and region he services (Toll Processor. Personal Phone Interview. June 23, 2018). Given this research challenge, the opinions of a diverse group of stakeholders was required to capture the complexities of the industry. Participants were located in 15 states across the United States and Canada with industry roles that ranged from haulers, brokers, processors, plastic engineers and end market users. Together, the interviews pieced together a comprehensive picture of market challenges and used to develop a set of

recommendations to increase the likelihood of program success if a PET processing facility were to be located in the Phoenix area.

3. Results

The featured graph demonstrates the most common opinions of the participants. The graph does not represent participants who did not give a response due to a lack of comment, withholding of information or inefficient knowledge on the topic.



3.1 Discussion

With regard to the aftermath of the China’s National Sword program, there was unanimous commentary on the state of plastic recycling in the United States. Every survey participant agreed China’s program was good for their own national environmental protection and ultimately presented a positive opportunity for the U.S. market. All participants expressed this was an opportunity for municipal governments, product manufacturers and citizens to realize the impact of plastics on the environment but also to realize the full economic value of recycling. Given that the participants’ occupations benefit from increased domestic recycling, their unanimous support for the closure of an international competitor is not surprising. Perhaps surprisingly, one anonymous participant recently lost their 20-year career as direct result from China’s ban. Even with their job loss, the participant supported China’s decision citing a strong desire for the United States to handle its own waste recycling (Anonymous. Defunct Plastic Brokerage Firm. Personal Phone Interview. Sep. 19, 2018).

All the participants discussed an increase in landfill dumping domestically. Some participants either had heard this information from first-hand sources or had personally sent recyclable material to a landfill to save costs or could not find a buyer for their material. All participants agreed that because of this increased amount of landfill bound material, landfill tipping fees have increased, and recycling fees have started to increase as well. All but one participant agreed it was necessary to increase consumer source separation. By having consumers pre-sort recycled material, it increases the value of the plastics by decreasing the backend costs and improving consistency of recyclable material in the United States. The participant who did not agree suggested that artificially intelligent sorting machines would solve these issues, leading to increased diversion rates and decreased labor costs (Anonymous Toll Processor. Personal Phone Interview. Sep. 6, 2018).

While all interview participants expressed optimism in the future of the recycling industry, they were split as to where the industry would be geographically located. PET and HDPE would continue to be processed in the United States, but only five agreed that the U.S. would rise to the challenge of handling all of its recycling supply and demand. Seven participants commented that an African nation would take over as the global recycling capital. The participants cited Africa's increased manufacturing economies, relaxed environmental regulations, large amounts of land and cheap sources of labor. Comparatively similar factors that led China's successful economic development and recycling market dominance (Esmail, Hanaa & Shili, Nedra, 2017).

3.2 Phoenix Processing Facility Case Study

The Phoenix metro area produces roughly 8,500 tons of post-consumer PET plastic annually. While this figure looks similar to the previous total used in the RISN report, the origins of

the aggregate amount are different. The 2017 RISN report stated that 4,859.8 tons were already being recycled and 4,245 tons could be captured from the Phoenix's municipal waste stream. According to the findings of this research, this claim is based on a bold assumption. Within the last five years, Phoenix has spent millions on campaigns that have proven ineffective in increasing its waste diversion percentage over 33 percent. This leads this researcher to conclude that in the short run and without significant policy changes, Phoenix cannot count on capturing any significant additional amount of PET from the 4,245 tons remaining in the waste stream.

The roughly 8,500 tons of post-consumer PET presented in this research paper is the result of aggregating local material recovery facility data throughout the Phoenix metro area. This data will be presented in an upcoming report from the Rob and Melanie Walton Sustainability Solutions Initiatives. The 8,500 tons represents material that is currently being sorted annually and does not account for any additional material which could be extracted from the municipal waste stream. If Phoenix were to build a facility, the local vendors of post-consumer PET would be able to ship their products within the state and benefit by the cost-saving in transportation expenses. In addition to a greater commodification of the municipal waste stream, aggregate totals could increase if a Phoenix facility were able to broker deals with other Arizona metropolitan markets such as Tucson and Flagstaff, as well as material from other privately-owned post-industrial sources. It is imperative that Phoenix increases its supply of post-consumer PET well past its current state in order to meet facility feedstock requirements.

There is a discrepancy when it comes to Phoenix's ability to run an efficient and profitable facility using its current amount of post-consumer PET. Some interview participants agreed that 8,500 tons of PET a year is the bare minimum amount of feedstock necessary to start a PET

processing facility while others insisted that more PET feedstock would be needed in order to break even with operational costs. As described by a representative from Bulk Handling Systems (BHS), the minimum is a requirement of the machinery used in the facility and tied to the operational costs. The grinding, washing, sorting and pelletizing machinery used in a plastic processing facility is expected to run 24/7, totaling around 8,000 hours annually. The recycling business is not known for its generous profit margins (Taylor, 2015), but this year—and in the short run in the United States—a large majority of the participants agreed that operators could expect to make a profit off of a productive and optimized facility.

Start-up costs appear to be prohibitive for some locations. Processing facilities require a major investment up front and sufficient revenue to support high costs of operation. Participants agreed that to even start a facility, there must be a significant amount of land ready for use and capital for a six-month runway. Large facilities in the United States utilize 200,000 to 300,000 square feet of space while a facility in Phoenix might be able to fit on a plot around 50,000 square feet. Including various start-up costs, land and equipment the capital needed to start a plastic processing facility of this size can range from \$15-30 million. When thinking about starting a facility, interview participants emphasized the importance of building a facility past current regional capacity. If the processing plant is a success in Phoenix, both local supply or demand may increase, and the facility would need to be able to easily scale by adding additional lines of operation.

Operational costs can be determined by a “cent-per-pound” measurement and include the labor, energy, water, chemicals, rent, insurance and maintenance needed for all stages of processing the PET. At current rates, operational costs approximate \$0.47 per pound of PET input, and given the 8,500 tons, the average operational costs would be just below \$8 million per year.

During every hour of operation, in a hypothetical Phoenix based facility, the machinery would process 1.07 tons of PET. While two participants agreed that they had seen machinery used by industry leaders like Krones, Erema and BHS operate at input levels of around 500kg, they insisted that it was not a matter of whether the machinery could process lower amounts but an issue of operational capacity and cost efficiency. A representative from Krones, a world leader in designing plastic processing facilities, reluctantly stated “that a facility processing 9,000 tons a year would give you a 24/7 operation and depending on certain factors allow you to break even on your operational costs (Larson, J. Personal Phone Interview. Oct. 25, 2018).” The representative also stated that Krones has built similar-sized facilities in Japan, Bangladesh, Germany, and South Africa but there were differences in those markets that allowed the facility to lower operational costs through cheaper labor or a larger stream of higher quality material. When constructing a plastic processing line, the machinery does not vary by size according to the amount of PET input. A wash-line processing 500kg of PET an hour will be able to process 10 times the amount with the same operational efficiency. By increasing the amount processed in an hour, the facility will be able to operate at a much lower cost efficiency. As one participant of the survey stated, “You will see better returns if you boost your material intake, the size of the machinery does not change, and you will use the same amount of operational inputs are required for one ton versus five tons of material per hour (Divekar, A. Personal Phone Interview. Oct. 5, 2018).”

In sum, research and elite interview participants have confirmed a PET processing facility located in the Phoenix would need roughly \$15-30 million in start-up capital and would have annual operational costs of around \$8 million dollars. In order to provide a viable plan for a Phoenix facility, the operation would need to generate enough revenue in order to cover the costs and provide a rate of return equal to the amount of the initial capital expenditures. Understanding

how a plastic facility generates revenue is tied directly to the facilities ability to yield the most plastic resin out PET containers including bottles, trays, lids, and clamshells within the facility feedstock.

The participants who specifically deal in processing PET were unanimous in their belief that the best feedstock for a PET processing facility is a supply of baled bottles. This uniform feedstock is most common in “bottle bill” states; that is, states that allow for recyclable material to be returned for a designated value. Material recovery facilities located in the Phoenix metro area do not produce bottle bales but produce mixed PET bales that have a lower average contamination rate than the national average mixed PET bale (Mariacher, L. Interview. May 25, 2018). Per the consensus of survey participants, when a mixed PET bottle bale enters the processing facility, the facility can expect a consistent quality yield of PET resin.

On average, a bale of mixed PET will contain a range of 80-90 percent clear PET bottles, 0-10 percent clear mixed PET containers, 5-10 percent green bottles, 0-5 percent blue bottles and 0-10 percent contamination which includes organic material, cardboard or various metals. Once the bale has been broken and sorted you are left with a stream of clear PET but is not completely contaminant free. Even in a 100 percent, clear PET bottle bale, there is still a 12 percent contamination rate from the labels, bottle caps, neck rings, glue and sticky beverage residue. Ultimately, after you lose around 8 percent of PET resin from lost particulate in grinding process, the total yield from a mixed bale of PET plastic is around 70 percent.

Given this previous percentage, this means a Phoenix facility could yield around 6000 tons of market-ready PET pellets. As of November 2018, the average price of clear PET pellet pound was \$0.67 which would produce yearly revenue just above \$8 million. As the interview participants predicted, a proposed Phoenix facility would be projected to break even in its first

year of operation. This meets the minimum operational expectations of the elite interviewees in the study. Unfortunately, at least out of the gate, the \$8 million-plus in annual revenue would earn very little profit that could be applied toward initial capital expenditure costs. Minimal first-year success would address concerns that a proposed, start-up Phoenix operation would be “cost prohibitive” and lay the groundwork for the hope to create a facility that would be profitable to the taxpayer and the environment over time.

3.3 Policy

Throughout the series of interviews, it was common for the interviewee to ask if Arizona is politically or institutionally ready for a statewide “bottle bill” deposit system for glass, aluminum, or plastic bottles. Most participants saw this type of legislation as the single most effective tool for the diversion of plastic from the waste stream and increasing the amount of plastic directed to a plastic processing facility. In a recent article, John Fischer, branch chief of commercial waste reduction and waste planning for the Massachusetts Department of Environmental Protection (MassDEP), stated there was “no other recycling program that has achieved the same rates as deposit systems. Meanwhile, we’ve seen materials recovery facilities face pressure to improve the quality of outgoing bales, and we don’t have that problem with bottle bill material (Karidis, 2018).”

California’s bottle collection rate hovers around 80 percent annually while Arizona struggles to break 35 percent. Given the success of California’s deposit system, an Arizona bottle bill should be similar (Abbott, 2018). The California scheme involves retailers collecting monetary deposits from consumers and then paying the deposits over to the state government. The used containers are not necessarily returned at retail locations but instead at redemption centers located around the state or placed in curbside recycling. This step avoids cumbersome additional

redemption related transactions between retailers, distributors, and the state. All unclaimed deposits would stay with the state, adding revenue to support related programs such as a proposed PET recycling facility in Phoenix (Bottle Bill Resource Guide, 2018). According to news reports, “California’s bottle redemption system, run by CalRecycle, pays for itself through unredeemed deposits, and \$120 million a year of the revenue it generates goes to other recycling programs and workforce programs (Karidis, 2018).”

Ten states currently have bottle bills with the first legislation passed in 1971 and the last enacted in 2002. A bottle bill is not a new solution and some states have struggled to get the bills passed in the United States. Most bottle bills face opposition from citizens claiming there is no need for another state-run system that levies a tax on bottles, retail stores object to using valuable floor space to collect dirty and sticky containers, and, historically, beverage manufacturers such as Anheuser-Busch, Coca-Cola and Pepsi that have actively funded opposition to new bottle bills (Granger, 2017). However, given these brands and manufacturer’s 2030 promises on using all reclaimed and recycled bottles in new beverage containers, it may be within their best interest to change their vote.

3.4 Technology

Another key takeaway from participants were the cited uses or interest in improved consumer friendly technologies to aid in the recycling experience and a point of source separation. One such piece of technology is a reverse vending machine (RVM). RVMs have been around since the 1920’s, but what used to be a simple coin return mechanism activated by a bottle is now a full-service automated machine able to scan, sort, and crush a plastic bottle while delivering the consumer a seamless recycling experience. As the consumer places the item in the machine, they are rewarded with cash or a voucher able to be tracked through an app.

TOMRA, the world leader in RVM production and implementation, is interested in spreading their machinery throughout the United States but is limited to states with bottle bills. Unfortunately, the economics of an RVM do not make sense without a deposit system. RVM's are ideal for retail spaces where consumers can deposit their recyclable material before beginning their shopping activity. TOMRA has eliminated the pain point for retailers by providing a machine that not only uses a low amount of square footage but contains the "mess" that is often associated with collecting post-consumer bottles.

With a new plastic processing facility in Phoenix, RVMs would fit well within a new circular manufacturing model. Due to an RVMs ability to attract material from the waste stream and separate recyclable material, RVM processed material has almost a zero percent contamination rate and is able to skip a material recovery facility, bound for a plastic processing facility. By skipping the material recovery stage, the plastic is higher quality, is able maintain more of its margin and ultimately making more money for the city and lowering operational costs for manufactures using recycled material.

A potential partnership between TOMRA and the City of Phoenix would not be complete without Arizona State University. ASU would offer an ideal scenario to run a pilot project for the TOMRA machines. The reverse vending machines would be able to collect an uncontaminated stream of recyclable material off the ASU campus while engaging the student population with cash, ASU gear or tickets from an integrated Sun Devil Rewards program. It is this type of creative partnership that would continue to make ASU a leader in innovation and sustainability and put the City of Phoenix on the national stage as a leader in achieving unprecedented, zero waste sustainability goals.

4. Recommendations

The city of Phoenix could build a PET processing facility in the metro area pursuant to two models. The first, the city could issue a request for bids from commercial companies interested in opening a facility in the Phoenix metro area. Even though Phoenix would likely offer a tempting deal on land, energy, and water, there may be very little interest in the private sector because most for-profit companies are focused on servicing larger amounts of PET than the city's expected 8,500 annual tons. All interview participants agreed that a preferred facility plan would be able to handle 30,000 tons of material a year, three and a half times Phoenix's current feedstock. While there are facilities that operate with a lower feedstock, they operate in states that have bottle bills that allow for a more consistent, lower cost and higher quality end product, and Arizona is not a bottle bill state.

The second way that the city of Phoenix could build a PET processing facility requires the city to assume most of the risk by providing capital for the project. This scenario relies heavily on a plastic processing facility offsetting the risks by providing an unprecedented opportunity for Phoenix to meet its sustainability and job creation goals. In this scenario, Phoenix would contract designers from Krones or Erema, international leaders in designing processing facilities, to build a facility. The city would then need to hire the appropriate talent to operate the facility. This model is not unlike what the city already does with its material recovery facilities. Phoenix owns the facility but hired out Republic services to operate the MRF. Through a revenue sharing agreement, the city could get a top-quality recovery facility and maintain ownership of the PET. Depending on the tolerances of Phoenix officials, the financial viability of the project could increase if there was less pressure on generating a profit for the taxpayers in the short-run. A longer-term strategy that favored the economic and sustainable impact provided by Phoenix's investment could increase the likelihood that an investment of this size would pay dividends for

years to come. In either scenario, the longevity of the facility and its ability to impact Phoenix's long-term sustainability goals would depend on increasing its diversion rate across the Phoenix metropolitan area and providing more, higher quality material for the facility to process.

5. Conclusion

Although this was a limited study based on qualitative interviews and some quantitative data derived from elite interviews of industry leaders, in the final analysis, it is clear that constructing a PET processing facility in the Phoenix metropolitan area would be feasible given certain favorable conditions. The City of Phoenix would benefit most from a facility they own but contract operation to local industry experts. This would relieve the economic pressure as a result of slim profit margins in the beginning years and allow for maximum public benefit in the long run. Project interview participants agreed this may be feasible and would be considered the first of its kind in the nation, demonstrating to other cities a viable solution for their sustainable future.

Further research should be conducted into how to develop a more robust local demand for recycled plastic and an more comprehensive trading market for recycled plastic. By increasing the local demand and enabling a better market, the local recycled plastic commodity market could become more competitive and even increase recycled plastic prices. Actions like these would ensure a Phoenix based, tax-payer support facility would not only be good for the public but ultimately profitable.

Appendix 1

PET / Plastic Industry Survey Questions

1. In which year was your PET processing plant established?
2. How much did your plant cost to get up and running?
3. Did you receive any government subsidies or tax incentives to establish the plant?
4. If so, how much and from who?
5. What was the motivation for setting up the processing facility?
6. Public demand, government goals, industry opportunity?
7. How large is the facility?
8. Is it custom or leased space?
9. What aspects of the PET processing cycle are implemented at your plant?
10. Where do you source your PET feedstock?
11. On average how much recycled PET does your plant process each year?
12. Who are your main customers that buy the recycled PET?
13. Where are these customers located: in-state, out-of-state, or in another country?
14. What types of product(s) use your recycled PET?
15. How many people were employed at your processing plant in 2017?
16. What were your total operating costs in 2017?
17. Did you have any capital expenditure in 2017? If so, how much?
18. Did you receive any form of subsidies or tax incentives from local or state governments in 2017? If so, what did you receive?
19. Please estimate your plant's share of the PET processing market (a) in your home state; (b) nationwide.
20. What major changes, if any, have taken place at your processing plant since it opened?
21. What do you think of the China ban on plastics?
22. What effects will this have on your plant, and the industry as a whole?
23. What major changes, if any, do you expect to take place in the next 12-18 months?
24. How do you think the industry will change in the next 5-10 years?

Appendix 2

List Of Anonymous Interview Participants

Location of Operation	Industry Specialty
Arizona	Recycled Plastic Toll Processing
Arizona	Recycled Plastic Toll Processing
California	Recycled Material Hauling and Brokering
California	Recycled Plastic Broker
California	Recycled Material Brokering and Consulting
California	Recycled Plastic Broker
California	Recycled Plastic Broker
California	Recycled PET Vertically Integrated Toll Processing
Florida	Plastic Processing Machinery Manufacturer
Florida	Recycled Material Brokering and Toll Processing
Georgia	Recycled Plastic Industry Consultant
Georgia	Recycled Material Hauling, Brokering and Toll Processing
Illinois	Recycled Material Toll Processing
Massachusetts	Plastic Processing Machinery Manufacturers
Montana	Recycled Material Hauling and Brokering
New York	Recycled Plastic Toll Processing
North Carolina	Vertically Integrated Recycled PET Toll Processor
Ohio	Recycled Plastic Toll Processing
Ontario	Recycled Material Hauling, Brokering and Toll Processing
Oregon	Plastic Processing Machinery Manufacturers
Oregon	Recycled Plastic Hauling and Toll Processing
Oregon	Recycled PET Toll Processing
Pennsylvania	Recycled Plastic Hauling and Toll Processing
Rhode Island	Recycled Plastic Toll Processor
Washington, DC	Recycled Plastic Industry Consultant

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