From Waste to Resource:

EVIDENCE-BASED PRACTICES FOR SUSTAINABLE SOLID WASTE MANAGEMENT IN A DESERT CITY(PHOENIX, AZ)

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INTRODUCTION

What is presented in this report? | One

The City of Phoenix has aspired to divert at least 40% of waste from the landfill by the year 2020. With increasing climate change impacts from greenhouse gas emissions as well as health hazards and pollution associated with solid waste land-filling (El-Fadel et al., 1995), the need to transform how we view and use waste is as pressing as ever. Although the Valley is not currently experiencing scarcity challenges for landfill volume and dumping sites, with a projected population increase to 9 million residents by the year 2040 (Gammage 2012), the need meet energy demands and reduce the environmental footprint of the city will create significant pressures for solid waste management (SWM). Phoenix is now looking to a circular waste loop, a loop in which "trash" is seen as a valuable resource rather than merely waste and given the city's 2020 deadline, Phoenix must develop and implement effective, evidence-based strategies in order to transform its solid waste system and meet its goals.

The City of Phoenix has aspired to divert at least 40% of waste from the landfill by the year 2020. With increasing climate change impacts from greenhouse gas emissions as well as health hazards and pollution associated with solid waste land-filling (El-Fadel et al., 1995), the need to transform how we view and use waste is as pressing as ever.

This case study was developed as an initial report to inform such strategy development for Phoenix. We present here an overview of best practices from around the world of cities that have achieved inspiring rates of waste diversion, with a primary focus on national comparisons and a secondary focus on international comparisons. In addition to presenting such practices that could help inform strategy development for Phoenix, we have also developed an initial list of indicators and sustainability targets to help the city assess the current state of its waste systems and infrastructure as well as track its future progress towards goals. Finally, using such best practices as well as lessons learned from such practices, we present an initial recommendation of next steps to help Phoenix reach 40% waste diversion by 2020.

Parameters for case study cities and methodology | Two

In order to provide accurate and useful best management practices (BMPs) for the city of Phoenix, it is essential to bound the chosen cities with parameters similar to that of Phoenix. Thus, given the city's overall goal of 40% diversion by the year 2020, we have chosen to select cities on one or more of the following parameters:

1. Required parameter: Cities that currently have a 40% or higher waste diversion rate
2. Required parameter: Cities whose population ranges from 1 million - 4 million
3. Optional parameter: Cities whose climates are similar to that of Phoenix

The information presented in this report was developed using an extensive literature review of scholarly sources, state and city documents, and additional organizational reports and publications. We also provide BMPs from Canadian cities as well as regions in Europe. Because most of the European cities that boast high diversion rates have small populations, we have also expanded our European comparison to a regional scale in order to fulfill both above listed required parameters. These cities were mainly selected using census and diversion data available from the Environmental Protection Agency (EPA) as well as literature review. A list of included cities within these bounds as well as information on population and diversion rates can be found in the Appendix.

Some of the challenges to bounding such a data selection include accounting for aspects such as climate and political environment. The climate of Phoenix as desert city poses issues for waste practices such as composting, challenges that have not yet been addressed in similar cities in the US Southwest. In addition, many of the cities reviewed in this case study have very different political climates as compared to Phoenix. These types of challenges are difficult to address in our scope of work but we see Phoenix as potentially becoming one of the most innovative cities to address such challenges.

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BEST PRACTICES (NATIONAL AND INTERNATIONAL)

Cities and Municipal Mandates | One

Though less applicable to the political climate of Phoenix and the state of Arizona in general, mandates for recyclables have been helpful in increasing diversion rates for several leading cities. Because mandates have been passed in the most committed of U.S. cities, such ordinances are always bolstered by education and outreach programs, grant funding and similar incentives. It is also important to note that the culture of many of these places radically differs from that of Phoenix. Arguably the most successful city in this area, San Francisco mandates both participation in recycling and composting for all single and multi-family residences in addition to commercial entities. San Francisco's current diversion rate is 80%, and is currently focusing on achieving a zero waste goal by 2020. In addition to the mandate, San Francisco devotes staff resources to provide trainings, signage, and door-to-door education sessions to city residents and businesses (City of San Francisco n.d.). In addition to this staff time, the city also has published an extensive library of guides and how-to manuals for residents and businesses. San Francisco has also passed legislation focused on specific sources of waste; plastic bags have been banned in the city since 2012, while compostable bags and paper bags are still subject to a small charge. Such symbolic legislation is a testament to where the city is in terms of the prioritization of the problem.

Other cities selected for this analysis with mandates include San Diego and Seattle. San Diego has also seen considerable success with setting mandates, achieving a diversion rate of 68% as of 2012. This same year, San Diego's recycling mandate was updated in providing more stringent standards for single and multi-family homes as well as commercial entities. The mandate provides a list of materials that must be recycled, and requires that "…privately serviced businesses, commercial / institutional facilities, apartments, and condominiums generating four or more cubic yards of trash per week are required to recycle." San Diego has made strides in providing readily available publications, especially for businesses and multi-family residential units, which had been difficult to reach in the past. Education campaigns in addition to this mandate have been helpful as well. The City also has provisions and regulations for new development and construction, as well as for special event recycling (City of San Diego n.d.).

Seattle's recycling program has been a work in progress, as standards and goals were revised in 2011. These goals were slightly more ambitious that what was actually achievable. Currently, Seattle diverts 55.7% of municipal solid waste. The City's original goal was 60% by 2012. Seattle faces challenges in increasing multi-family recycling, which has been significantly less successful than single family curbside pickup and commercial regulation. Seattle's recycling ordinance was originally passed in 2005 for both single family homes and commercial entities, and has been revised recently in 2014 to reflect more stringent standards for businesses (City of Seattle, Public Utilities, 2013).

Mandates typically become more restrictive over time. Cultural shifts as well as improvements in municipal infrastructure and education programs help drive this increased stringency. However, municipal ordinances restricting choice have been criticized heavily even in highly progressive cities. Mandates can also be taxing to staff time and capacity, as cities also must invest staff time in inspecting bins and tracking violations. Because of these issues, it is important to have a strong "infrastructure" of programs prior to attempting to pass a mandate. Mandates should evolve with local culture, and progress with this evolution. This being said mandates can help reinforce the current practices of both residents and commercial entities.

Public-Private Partnerships

There are several things that municipalities can do to incentivize private industry to increase diversion rates, and assist in meeting municipal targets. Public-private partnerships provide the structure for collaboration and idea-sharing between local governments and businesses. They also provide a platform for regionalization. For example, the Florida Recycling Partnership integrates several private sector partners with municipal partners in order to pilot recycling programs and complete comprehensive industry specific studies. Other organizations such as the Southeast Recycling Development Council also points members to waste exchanges, and further opportunities for collaboration in reuse and recycling. In serving as the role of a facilitator in a wider network, RISN will also provide a valuable space for collaboration. This is especially important considering the relationship Phoenix has as a leader among other cities in the Valley.

Incentives

In addition to these networks, providing incentives can also be highly effective. There are state incentives for private sector recycling. The state of Arizona already has an incentive program where individuals and corporate groups can claim a 10% tax credit on recycling equipment (EPA, 2013). Incentives such as these might be encouraging, but city incentives would also be helpful to offer. Commercial waste can account for around 50% of a municipality's generated waste, so it is important to consider in terms of increasing a municipality's overall diversion rate (MCLUESA, 2011). Several cities employ less restrictive mandates specifically targeting commercial entities. Some place caps on the types of recycled material added to the waste stream, while others focus on the amount of waste produced such as Fresno, CA, or the number of employees a commercial entity has, as Austin, TX does. Chicago makes a certain degree of recycling mandatory in order to receive a business permit (MCLUESA, 2011). Pay as You Throw (PAYT) programs can also be effective in incentivizing businesses to innovate. These programs both in the context of commercial entities as well as residential groups can have a large impact on diversion rates, increasing diversion by a total of 8%-11% in some cases (Skumatz and Friedman, 2006). However, these programs do have the potential to be problematic in terms of contamination of recyclables, which will be discussed later on in this analysis.

Cities also have supplementary programs in addition to any mandates or ordinances. Business recognition programs, grant funding, auditing services and free assistance are commonly offered by cities with high diversion rates. Free recycling services to businesses that comply with certain ordinances are also strong incentives. For example, the state of California used to have a grants and funding system that businesses and commercial industry could apply to in order to fund diversion projects (California Recycles, 2014). Such grants were helpful in providing businesses with resources. Cities which do not provide pick up services should provide drop-off facilities for bulk recycling, and open these services to commercial entities. Cities, Phoenix included, should continue to strive for ways to not only regulate business activities, but to provide meaningful incentives for voluntary participation and innovation. This is likely where the low hanging fruit is for a city with a political environment like Phoenix.

Cities and Technology | Three

Technology is a focus of many interested in innovation in municipal waste. One option that the City of Phoenix and many other cities currently operate with is Materials Recovery Facility (MRF). As part of this study, the City of Phoenix's North Transfer Station and MRF was visited in order to gain insight into the process. The main building has a Transfer Station processing capacity of 4,000 tons per day (TPD), and a MRF capable of processing 400 TPD of commingled recyclables (J.R. Miller & Associates, 2013).

MRFs can either be mixed or single stream. Mixed facilities take municipal solid waste or "black bag" disposal and process it in order to recover recyclable materials. Single stream MRFs take "blue bin" materials and sort comingled materials so that they are able to be processed and sold to vendors. There are advantages and disadvantages to each type of facility in principle. Single stream facilities may "miss" some of what is being thrown away by residents. Mixed stream facilities process all waste, which in theory should increase diversion rates. However, they are more costly, and require more advanced technology in order to process waste efficiently (Urban Sustainability Directors Network, 2014). They are helpful in that they provide a processing feature that makes continual citizen education campaigns less necessary. In this way, these types of facilities can be successful community investments. For example, the mixed waste MRF built in Placer County, CA in the late 1980's was originally performing very poorly in terms of material recovery. However, later on, after adapting the facility in order to accommodate for hazardous waste, food waste, and other such issues, it became much more productive in its later years (Dickinson, W., 2013). Mixed use MRFs are much less commonly operated compared to single stream facilities. Many cities have evaluated these facilities as an option but choose more traditional curbside pickup methods instead. This is also because though costs on the collection side are significantly lowered, the labor intensity and therefore cost of sorting waste input is much higher. Cities are also less willing to choose this option because it is more unconventional and less common; success is less guaranteed and proven.

In terms of diversion rates for either method, facilities that process "black bin" waste can have highly variable rates of diversion. A 2002 study describes that these mixed use MRFs divert 10%-30% of material (Strange, Kit, 2002), while a publication from the Urban Sustainability Directors Network (USDN) provides a large range of 5%-45%. These large ranges and past issues with low recovery rates have made it difficult for municipalities to gauge how successful such models would be. An economic study completed for Washoe County, Nevada outlines several scenarios and the costs and benefits of both black bin and blue bin processing facilities. In these scenarios, it is found that the "clean" method of processing exclusively recyclables is more cost effective and produces higher diversion rates. However, this is not the case in a large MRF that processes black bin materials; that is to say that a facility that is able to process 50% or more of municipal solid waste will be both cost effective and achieve a higher level of diversion and materials suitable for purchase by a manufacturer (Harris, et al, 2011).

There are newer technologies that have been recently explored in Europe and parts of North America. Thermal technologies for waste to energy conversion are currently being explored and are much more popular in Europe compared to North America. For example, a plant just north of Malmo in Sweden currently uses incineration techniques. They are able to supply a large amount of energy through this plant; 40% of homes in the city are powered by energy created from the combustion of waste (ICLEI, 2006). These techniques reduce landfilling but produce a high amount of GHG emissions and therefore are less advisable. Other alternative thermal technologies (ATT) that can be combined with MRFs are gasification, plasma gasification and pyrolysis. These relatively new processes produce syngas, which can be converted to energy. They each require a high amount of pre-treatment, and it can be difficult to argue for their cost effectiveness, especially as these are considered emerging technologies. However, they represent promising alternatives to pure incineration in the waste to energy research field. Pilot plants that perform plasma gasification in these fields are present in North America in major Canadian cities such as Ottawa. Their output varies with the exact application of the technology. Capital costs can be quite high; the facility in Ottawa for example was built for around $22,000,000, and produces an output of 823,367 kwH of electricity. It is able to divert 6,600 tons of waste annually through this conversion process Performance of this plant is still somewhat unproven and untested. Many of these alternative thermal technology plants that have been built in Europe, Japan and North America are pilot projects (Urban Sustainability Directors

Network, 2014). Tipping fees must also be set much higher as these thermal technologies are still very high cost (Youngs, 2011).

For Phoenix, in moving forward with organic waste, anaerobic digestion should be something that is highly considered. Anaerobic digestion, though costly, can be helpful in terms of producing energy as well as compost. This would also require the City of Phoenix to begin working with food waste as well. Anaerobic digestion is also something that high achieving cities are exploring and implementing. The City of San Jose recently opened the nation's first large scale commercial anaerobic digestion facility, diverting 30,000 tons of food scraps from restaurants and groceries in the first year of operation (Skadowski, 2014). This facility serves as an example of what Phoenix can pursue on a smaller scale.

Cities and Food Waste | Four

The best practices for managing food waste in more sustainable ways for the city of Phoenix fall into two categories: targeting upstream and downstream practices. The following is an overview of the best practices in both categories for the case comparison cities.

Upstream practices for food waste are targeted at reducing food waste prior to the disposal phase. These types of practices include conducting waste characterization assessments, establishing standard operating procedures for restaurant disposal (Food Waste Alliance 2014), and seeking collaborative partnerships with donation agencies for excess food. The City of Phoenix, in partnership with ASU, is currently involved in conducting a residential waste assessment audit (Tracey-Noren 2014). However, a commercial waste audit for larger businesses in Phoenix may provide the city a means of identifying areas to channel implementation and investment in reducing food waste. In reference to donation programs, the City of San Francisco has collaborated between public and private agencies to collect food from wholesalers and redistribute to food banks and service agencies throughout the city (EPA 1998). The program required working with local food donation organizations, identifying regional markets for inedible food, contracting with hauler services, and providing monitoring and assessment given federal food regulations. The State of Massachusetts (EPA 2013) as well as New York City have developed similar voluntary programs for supermarkets, stadiums and arenas to donate excess food to needed services (Science Applications International Corporation 2000). Through these types of programs, Massachusetts' commercial supermarket sector has achieved a 60-75% waste diversion rate and participating restaurants and arenas in New York City diverted an estimated 52,000 pounds of food waste and 8,000 of reusable goods respectively in the year 2000. The City of Los Angeles has also recently implemented a pilot food waste recycling program for voluntarily participating restaurants across the city. in 2011, Los Angeles' food waste recycling program diverted over 43,000 tons per year of compostable food and paper from the landfill (City of Los Angeles 2013).

On the city level, few best practices exist to enforce or mandate such initiatives. However, some cities have taken steps to foster these practices. The cities of San Francisco and Seattle have played a large part in forging the path for composting by instituting a Mandatory Recycling and Composting Ordinance for both residents and businesses as previously mentioned. The City of New York is also set to begin enforcing a new Commercial Organics Law for large scale food service establishments beginning July 2015 (City of New York 2014). This commercial mandate began with a 2013 mayoral "Food Waste Challenge", challenging private sector groups in New York to voluntarily reduce their total amount of food waste in order to help increase the city's 55% diversion rate (Government of District of Columbia n.d.). The 2013 challenge resulted in restaurants diverting more than 2,500 tons of food waste from landfills through compost or donations (Strom 2014). The mandate has given food service establishments two years to develop the appropriate infrastructure to be compliant with the 2015 mandate and the mandate will be enforced by the NYC business integrity commission, the Sanitation Department, the Department of Health and Mental Hygiene, and the Department of Consumer Affairs.

The large portion of BMPs for managing food waste on a city level are targeted at downstream drivers, or practices aimed at this waste after disposal. Cities such as San Diego, San Francisco, Seattle and Portland have implemented curbside programs. However, these types of programs require large amounts of capital and infrastructure to provide services to all city residents. Perhaps the most poignant and relevant example of lessons learned for large-scale city-wide food collection programs can be drawn from Denver, Colorado. The City of Denver implemented a pilot program in 2008 for curbside organics collection, however, due to the wide-spread area of pickup, collection routes became too costly to continue the program (Freeman & Skumatz 2012). The city has now implemented a compost collection program in designated areas throughout the city and has increased costs for the fee-based program. However, many areas outside of the downtown vicinity do not have access to this program. Similar to Denver, Phoenix has developed over the years into a sprawling metropolis and if such a program is developed by the city, could face similar challenges.

Collaborative partnerships may provide Phoenix an alternate pathway for such programs. The City of Cambridge pursued a collaborative partnership with a local recycling hauler, contracting curbside services to collect and transport business and institution (schools, city building) feedstocks to local farms to be used as composted fertilizer for crops (Tucker 2007). Although Cambridge sits beyond the bounds of city-to-city comparison for this case study, give the sprawling layout of Phoenix, this type of contracting partnership may provide more feasible means for the city to pursue a food waste program. However, there are some associated challenges to these types of partnerships. For example, ordinance and code enforcement in the city of Dallas pose significant challenges over regulating composting on a city wide-scale. However, local partnerships between private companies and contractors have been able to work with City Council to ensure code regulation and overcome bureaucratic hurdles such as delays in composting permits and food waste storage compliance (Nicholson 2012). For the city of Phoenix, partnering with companies such as Recycled City to contracted pick-up cities in conjunction with focus on regulations, mandates, and codes can provide a foundation to expanding food collection services throughout the city.

Incorporating food waste in existing yard waste composting facilities has also been undertaken by various cities in developing a food waste program. This type of program requires existing yard waste compositing infrastructure that can be retrofitted for food residual (Christensen 2009). This type of programming requires knowledge of feedstock residual composition in order to accurately and effectively plan appropriate infrastructure and process requirements for retrofit. Regulatory procedures must also be developed by the city in order to insure health and safety compliance for both users and service providers. This type of retrofitting has been undertaken by Portland (City of Portland n.d.) and San Diego (City of San Diego n.d.). The phased development of the "Green Organics Curbside Collection" program in Phoenix could provide a platform for such an integration to be implemented to address food waste throughout the city.

Cities, Education and Outreach | Five

Best management practices for education and outreach to community residents provide a resource for many cities that do not currently have mandates to reach diversion goals. These include elementary educational programs, annual specialty recycling events, community composting centers, and public-private partnerships. Community-scale projects such as community composting centers similar to those developed in New York City, can provide communities funding and support for planning and implementing community-scale solutions to reduce waste and encourage fresh food production through home or community gardens (Datz-Romero 2014). In addition, creating small-scale community teams such as the "Residential Recycling Teams" in San Francisco, can promote more engaging pathways for promoting waste diversion in neighborhoods through tools such as events and residential building waste assessments (Yepsen 2009). Robust elementary school curriculums such as those found in Los Angeles (City of Los Angeles 2013), Vancouver (MCLUESA 2011), and San Francisco that have mandated expansion of these programs to upwards of 90% of schools in these cities can also increase awareness and outreach for community members. The City of Vancouver also offers hands-on workshops for composting and interactive waste reduction websites for communities.

Other innovative BMPs for residential outreach and education include the "Red Dot Program" in Vancouver and the "Garbage Purchase" program in Curitiba. The "Red Dot Program" allows residents to use red dots on mailboxes to prevent the postal service from delivering junk mail to residences (MCLUESA 2011). Finally, the city of Curitiba, Brazil provides a "Garbage Purchase" program for low-income residents in which community members can collect and separate recyclables from residences and businesses and in the streets in exchange for bus tickets and agricultural products, a program that has proven to cost the city the same amount as contracting private companies to collect the garbage (Rohn 2007).

Many of the outreach programs listed above require robust stakeholder and community engagement processes. For example, San Francisco conducts extensive door-to-door outreach to citizens through its "Green Jobs Team"(City of San Francisco, n.d.). San Jose's Commercial Solid Waste System Redesign project in 2008 sought to directly involve stakeholders such as retailers and community members through surveys, case study interviews, presentations and workshops to address issues such as food waste and plastic bag waste (City of San Jose 2008). These types of processes can be time and resource extensive, requiring trained facilitators, effective participatory materials, and follow-up and can be met with challenges such as conflicting interests and unwillingness to participate. These types of challenges require careful planning and design as well as skilled team members who are trained in effective participatory facilitation. It is also essential that cities utilize the appropriate tools and techniques for successful engagement (e.g. surveys v. workshops v. interviews).

For outreach and education for the business and private sector, many of the case comparison cities provide assistance programs for businesses as well as exemplary policies for city buildings and departments. Cities such as Los Angeles (City of Los Angeles 2013) and Toronto (MCLUESA 2011) engage in public-private partnerships to provide waste characterization studies as well as support for zero waste or waste reduction strategies for businesses and health facilities. The European region of Flanders provides an "eco-efficiency assessment" program to help identify intervention points for areas such as waste for small and medium companies. The region has also identified an online case study database of businesses that have met certain waste diversion criteria. The region also provides an online tool database to help events reduce and increase waste diversion (GAIA 2012). These types of programs require collaborative partnerships with consulting agencies that specialize in waste assessments as well as outreach programs (media campaigns, tax incentives) to promote businesses' participation. Finally, implementing preferred purchasing policies for city departments as well as designating city buildings as "zero waste" buildings as in Los Angeles can provide businesses an on-the-ground case study example in how to design and implement for zero waste operations.

Cities and Reducing Waste Contamination | Six

Contamination is a major issue in terms of how it affects recycling rates. An important point to note is that recycling or diversion rates do not account for losses through contamination. Therefore, diversion is only one metric that describes how efficiently a city recovers materials. EPA standards for calculating recycling or diversion rates do not actually account for contamination in the formula (New York City, 2004). Another clarification that is necessary to make is that measures of contamination very much vary between municipalities. Some take this number as the residual figure from a municipal MRF, while others find an estimate via sampling and bin inspections. In this way, the figure is less comparable between cities in comparison to the diversion rate. In addition, contamination can be highly costly for municipalities in reducing the materials available for purchase by manufacturers. There are several factors in the waste stream that can create issues of contamination. Contamination can occur when the materials received by a facility are already contaminated in some way. Residents can put non-recyclable materials into recyclable bins, or material that is potentially recyclable that the community's facility does not have the ability to process. Most municipalities do provide some sort of public education program in order to reduce the frequency of such behaviors (EPA, 2014).

Even when recyclables are collected through a mixed, single stream, there is still the need to provide education to residents in regards to acceptable material, and how material might need to be prepared prior to collection. Changes in program design can lead to increased contamination. For example in 2004, when the City of Los Angeles switched some areas of the jurisdiction to recycling bins, contamination increased from 10% to 25% (New York City, 2004). This very high contamination rate is something that prompted the launch of the education and outreach campaigns described in previous sections. The City views education as a much more crucial component of reducing contamination rates, versus monitoring, though sampling checks are completed occasionally.

Other cities have seen success with education campaigns. The City of Atlanta for example does not currently penalize citizens for contamination. The rate of contamination for the municipality was 7%, though door-to-door education has helped in slowly decreasing this rate (Debronsky, 2010). Multifamily unit contamination as well as participation has never been as ideal as participation by single family homes. Targeting education towards this demographic has been a key initiative in several cities including Seattle, Culver City, CA and many more. This has also been a recent focus in cities in Britain, with Bristol and London creating long term engagement programs, focused on reaching residents instead of property managers (Cascadia Consulting Group, 2012). These grassroots programs, documented by Cascadia Consulting Group showed that targeted outreach is important in that if "problem area" neighborhoods and designations are targeted, there will be a greater impact on overall contamination rates, as well as diversion rates, as neighborhoods who produce high contamination are typically the same neighborhoods with low recycling participation. Seattle has also spent a lot of time and energy focusing on combating this issue of multifamily unit contamination.

Extended Producer Responsibility (EPR) laws and mandates on a statewide level have an effect on contamination. EPR laws shift material costs from the government and tax payer to the producer, and indirectly, the consumer. These have been implemented as statewide laws in both Washington and Oregon for different types of E-Waste and hazardous material, which tends to be problematic in MRFs that process black bin waste, and even those that exclusively process recyclables. British Columbia is considering a law much more stringent that would extend this responsibility to printed paper and consumer packaging (Cascadia Consulting Group, 2012).

Contamination reduction can also occur in the process of collection. If collection is entirely automated and the driver of a truck is unable to get a surface view of what is being collected at each residence, contamination by residences unaware of recycling standards may continue. If there is a means that allows drivers to monitor collection, they can then also be responsible for posting notices to residences improperly disposing of non-recyclables (EPA, 2014).

On the processing side, cities must be clear about clean processing targets and offer incentives to contractors in reporting higher materials recovery, and cleaner loads. Though contamination is thought of as an issue related to city residents and improper disposal, improper processing is an issue that can create high residue rates at MRFs. Residue is what ends up unprocessable of recyclables that are brought in from the municipality. To clarify this point, residue is often the terminology utilized as a synonym for contamination in reference to a MRF. Regular reporting is helpful in defining standards for MRF contractors (EPA, 2014).

Other cities do implement disincentives for contamination, usually in the form of fines. The City of Fresno in California implements a tiered fee structure depending on the number of consecutive violations registered to a residence. This has been relatively successful, as the City of Fresno currently has a diversion rate of 74%. Seattle has a similar program to reduce contamination (MCLUESA, December 2011).

A quality standard between a private sector processor and a municipality should be well established. Reporting to the municipality should not only occur by the processor at the MRF, but also the manufacturers purchasing recycled materials. Manufacturers must especially be clear about the level of expected quality for materials sold and communicate this to the municipality, as well as the operating contractor working with the city. The necessary quality that a city needs to receive from both its residents and processing contractor is highly dependent on the manufacturers purchasing processed recyclables. Therefore, it is extremely important for cities to create and maintain standards based on these purchasing needs (Kinsella & Gertman, 2007).

INDICATORS AND TARGETS FOR SUCCESS

Why do we need indicators? | One

Given the complex, integrated nature of sustainable waste management systems, assessing the sustainability of a current system or planning for a future system cannot be done with only looking at diversion and contamination rates for waste. Using these rates as the primary and only indicators to track progress does not address waste reduced at the source (upstream drivers) as well as additional drivers in the system (such as access to service, user/provider inclusivity in the SWM systems, and the degree to which reduction of solid waste is a priority for local governments) (Visvanathan 2012). We provide here a list of compiled indicators to help assess the sustainability of waste management practices for Phoenix in the future. These indicators were selected to address a set of goals for sustainable waste management. These goals are based on a review of scientific literature and reference documents. Given these goals, a set of performance indicators were identified in order to operationalize the goals. These indicators were determined through literature that suggests a clear link between general goals and measurable indicators. Targets or ranges for each performance indicator were then identified through literature review and can be used to facilitate the assessment of the sustainability or unsustainability of the current state of Phoenix's waste management system and track future progress. Indicators facilitate description of the current state through data collection. Yet, they are insufficient for operationalizing the goals of sustainability/livability. This requires targets (one for each indicator) that are discrete (quantitative or qualitative) thresholds (or ranges) that define, all together, sustainability of a system (Wiek & Binder, 2005; Rockström et al., 2009; Machler et al., 2012). Assessment of the sustainability/unsustainability of the current state of waste management systems can then be based on comparison of current state data (for each indicator) to the identified targets (distance-to-target).

Indicators and Targets | Two

The four major goals and related indicators identified for the sake of this case study are as follows:

Equitable governance in SWM systems

Sustainable waste management systems must provide integrative capacity building for stakeholders (both users and providers) such that each stakeholder plays a pivotal role in implementing SWM policies (Bjerkli 2013; Abas & Wee 2014; Wilson 2007; Ahmed & Ali 2006). In addition, civic players must insure transparency and accountability in developing and implementing such policies in order to build trust and fairness.

1. *User /provider inclusivity* is presented here as a proxy to determine the extent of stakeholder engagement in implementing SWM policies.
2. *Institutional coherence* is used as a measure of the extent to which sustainable SWM policies and systems are a institutional priority for local government. This is especially essential in assuring accountability and transparency for civic entities in these processes and systems.

Environmental control and protection SWM systems

Sustainable waste management systems must focus not only on reducing consumption, but protecting the environmental systems in which waste is processed. This includes a focus on the impacts on climate change these systems may have as well as enhancing the communities of residents and citizens (Waste Management n.d.; City of Florida 2014; Connecticut Department of Energy & Environmental Protection 1993).

1. *Controlled Disposal* is used as a measure of protection of local ecosystems against illegal dumping.

2. *Greenhouse Gas Emissions (GHG)* of SWM systems is pivotal to insuring sustainable waste management systems are addressing not only the GHG Emissions involved in the production of materials but in the disposal and processing of such materials.

Protection of public health and access in SWM systems

Sustainable solid waste management systems must provide residents and other stakeholders access to the appropriate services for proper waste disposal that supports a circular waste system (Wilson et al. 2012). In addition, SWM systems must not pose any health or otherwise detrimental hazards to residents and the general public (Anderson 1964; Maryland Department of the Environment n.d.; Hamer 2003).

1. *Households with three-tier collection service (Collection Coverage)* is used as a proxy to determine residential access to necessary services.
2. *Commercial facilities with access to composting facility* is used as a proxy to determine commercial access to necessary services.
3. *NOTE:* We have not provided indicators to address the public health component of this goal as this is an extremely complex problem constellation and is beyond the scope of work for this case study.

Focus on resource management and value in SWM systems (upstream and downstream)

Sustainable solid waste management systems must seek to reduce both waste at the source (upstream) and waste that is placed in landfills (City of Phoenix 2014).

1. *Source Reduction* is used as a measurement of reducing waste at the source through Extended Producer Responsibility and other upstream drivers.
2. *Waste Contamination* is used as a measurement of outreach and education of proper waste disposal procedures.
3. *Waste Diversion* is used to measure the reduction of overall waste in the landfill as well as the amount of waste processed using alternate means (recycling, composting, etc.)

Table 1. Goals, indicators, and targets for sustainable SWM systems

GOAL	INDICATOR	MEASURMENT	TARGET	SOURCE
Equitable governance in SWM systems	Institutional Coherence of Integrated SWM Planning and Implementation User and Provider Inclusivity in SWM Planning and Implementation	Degree of institutional coherence of waste reduction programs* Degree of user and provider inclusivity*	HIGH* HIGH/ HIGH*	Wilson et al. 2014 Wilson et al. 2014
Environmental control and protection SWM systems	Controlled Disposal	Percentage of waste that is disposed of legally Reduction of amount of GHG Emissions released by waste treatment (landfill and transfer stations) from 2014 levels	>95-100% >25%	Wilson et al. 2014; California Recycles 2013 US E.P.A. (2006)
Protection of public health and access in SWM systems	Households with three-tier collection service (Collection Coverage) Commercial facilities with access to composting facility	Percent of households with coverage Miles organics must travel from commercial facility (with output of more than 18tons/year) to composting facility	>90-100% <55 miles	Wilson et al. 2010 Chittenden SWD (2012); Howard (2013)
Focus on resource management and value in SWM systems (upstream and downstream)	Source Reduction Waste Contamination Waste Diversion	Legal ban on plastic grocery bags used in commercial operations Per capita waste Percentage of contaminated recyclables Percentage of waste diverted from landfill	YES Not Available <10% >50%	None Not Available (see data in Table 3- Appendix II) (see data in Table 3- Appendix II)

** See Table 2 in Appendix I for explanation of how these indicators are measured and assessed.

From Waste to Resource

CORRELATION BETWEEN CONTAMINATION AND DIVERSION

Contamination rates have the potential to interact with programs designed to increase diversion. Mandates discussed in previous sections have the potential to increase contamination, as citizens and commercial entities have a greater incentive to add non-recyclable material to recyclable or composting bins. Though mandates are promising and have been taken on by several leading cities to increase diversion, it is understood by the industry that these also incentivize negative (Cascadia Consulting Group, 2012). For example, a study revealed San Jose's 2002 introduced PAYT program actually increased the amount of garbage put into recycling bins, as residents were incentivized to reduce the amount of black bin waste in any way possible. Because of this, San Jose had a much higher contamination rate as compared to its San Diego, which does not have a PAYT program. San Jose's issue with contamination also stems from the fact that the city provides a much larger recycling container than a black bin garbage disposal, in order to further incentivize residents to send less material to the landfill. However, this has led to residences adding unusable material to their recycling bins just to dispose of it. This issue is seen to be common with PAYT systems, and with small black bin containers. Increasing education efforts helped with this issue enormously, and after a difficult beginning, San Jose's residual rate fell to 17.3% in the following fiscal year (Conservatree, 2005). Other such initiatives like less frequent collection, implemented in the City of Portland and others can also lead to improper recycling behavior. Populations must adjust to new programs; therefore, contamination occurs at the initial start of a new initiative, and can be reduced with proper education.

Municipalities should be mindful of secondary effects such as these when defining programs and policies. This being said, an increase in diversion can lead to a positively correlated increase in contamination. For example, in Seattle, contamination actually increased 4% from 2008 to 2010 for single family residents when mandates for recyclables began much more stringent. This was matched by a 6% increase in multifamily units. Programs associated with higher diversion rates, such as implementing comingled recycling, imposing fees on high levels of garbage collection can also lead to increased contamination.

From Waste to Resource

RECOMMENDATIONS

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Moving forward, the city of Phoenix would be best suited to pursue public-private partnerships in moving towards the city's 40% diversion goal by the year 2020. Given the political environment of the Valley, a cultural shift in how the city and its residents view waste is essential to this program's success. Passing mandates for required recycling and composting may not be feasible for Phoenix and thus, focus should be put on building a strong infrastructure of programs geared towards increasing diversion and decreasing contamination.

Because the percent and characterization of commercial waste is unknown for Phoenix, conducting an initial waste audit assessment for the city's commercial sector would provide the city insight into the potential areas for strategy development as well as challenges for reducing the commercial waste stream for landfill. In addition, as previously discussed, public-private partnerships can provide the city spaces for collaboration and innovation between government and businesses. Such programs would require transparent engagement with business stakeholders in order to develop successful collaboration. In addition, developing such partnerships may require bringing in independent consulting firms to provide technical assistance (Massoud & El-Fadel 2002).

Such partnerships can also provide strategies for addressing issues such as food waste and educational outreach. Due to the urban structure of Phoenix, developing and implementing a curbside collection for food waste may be challenging. Thus, forming partnerships with organizations such as RecycledCity may provide pathways for the city to begin to incorporate food waste within its waste processes. These types of contracts, however, must be complemented with the appropriate code updates in order that citizens are encouraged and supported in composting residential food waste. Encouraging businesses to either participate in such composting programs or develop on-site composting through incentives such as tax breaks or subsidies as well as city campaigns can also foster growth in this area. Additionally, mandating food waste processes such as composting for larger food commercial entities (for example, an annual output of 18 tons of food or more) can pave the way for building such infrastructure in the commercial sector. Finally, capitalizing on the existing Phoenix pilot program for green organics and retrofitting such infrastructure for the addition of food waste may provide the city the most effective and efficient means to addressing the 14.5% of food waste produced city-wide. Guides such as the US Composting Council's "Best Management Practices for Incorporating Food Residuals Into Existing Yard Waste Composting Operations" can provide support in how to implement such retrofits. Finally, in order to benefit from the food waste industry, the city of Phoenix must develop strong marketing strategies in order to capitalize upon the final compost as a product, and in the long term, possibly explore energy conversion technologies.

Some of the most challenging barriers in addressing waste streams throughout the city include the political environment as well as community and resident perceptions of issues of waste. In addition to providing economic incentives on a commercial as well as residential scale, education and outreach provide the most promising coping strategies for overcoming these barriers. On a residential and community level, developing and implementing city-wide educational curriculums for elementary schools may increase community awareness and reduce issues such as waste contamination. In addition, pursuing community partnerships through nonprofit organizations such as Love Your Block in order to provide communities grants and support to develop infrastructure such as community composting centers may provide promising pathways to address residential waste streams. These types of programs can also perhaps provide opportunities to develop community "Waste" teams designated to increasing awareness and action on a community level. Targeting low performing neighborhoods can also help build the desired culture and commitment. Once this is established, ordinances and mandates could possibly follow, but only after program infrastructure and local culture adapts to these values. Finally, on a larger scale, the city of Phoenix can provide inspiring and innovative models for zero waste operations by retrofitting existing city operations and buildings for zero waste. These types of "living" buildings can inform future strategy development for the private and public sector as well as characterize Phoenix as a leader in sustainable solid waste management for desert cities worldwide.

Appendix

APPENDIX I

Table 2. Explanation of user/provider inclusivity and institutional coherence (Wilson et al. 2014)

Governance strategies		
User inclusivity	Degree of user inclusivity	Composite score on a set of quality indicators allowing a yes for present and a no for absent. Represents the degree to which users of the solid waste services (i.e. households, business and other waste generators) are included in the planning, policy formation, implementation and evaluation of those services. The indicators are: 1. laws at national or local level that require consultation and participation with stakeholders outside the bureaucratic structures 2. procedures in place/ evidence of citizen participation in the siting of landfills or other treatment facilities 3. customer satisfaction in the waste management services being measured at the municipal level 4. feedback mechanisms between service users and service providers 5. citizens committees in place that address WM issues
Provider inclusivity	Degree of provider inclusivity	Composite score on a set of quality indicators allowing a yes for present and a no for absent. Represents the degree to which non-municipal waste service providers from the formal private, community or informal sectors are included in the planning and implementation of solid waste and recycling services and activities. The indicators are: 1. laws at national or local level in place which encourage public-private partnership (PPP), private sector participation (PSP) or community based organisation (CBO) participation 2. organisations or platforms in place which represent the private waste sector (formal, community-based or informal) 3. evidence of formal occupational recognition of the informal sector active in WM practices or recycling 4. evidence of protection of informal sector rights to operate in WM 5. little or no institutional or legal barriers for PSP in WM in place 6. institutional or legal incentives for PSP in WM in place
[redacted]		
Institutional coherence	Degree of institutional coherence	Composite score on a set of quality indicators. The first four indicators assess policy and the degree of municipal control: 1. Are there any sustained policy commitments to sustainable solid waste management? 2. Is there a clear and transparent policy framework for the planning and implementation of waste management practices? 3. Are authorities allowed to retain the revenues collected from the municipal fines and charges or to levy direct charges for services? 4. Are the out-sourced municipal waste collection services defined, supervised and controlled by the municipalities? The remaining two indicators assess the degree to which the solid waste budget is directly controlled by one responsible department within the city, and the degree of management control over WM which that department has (based on a qualitative assessment of the organisational chartof the city).

** Note: the qualitative indicators (4A, 4B and 6) are first scored on a % basis (e.g 20% for a 'yes' where there are 5 indicators or 16.67% where there are six indicators), and then translated into a 'HIGH' (71% and over), 'MEDIUM/HIGH' (61%-70%), 'MEDIUM' (35-60%) or LOW (33% or below) rating.

APPENDIX II

Table 3. List of Cities and Best Management Practices

Cities	Population (2013 Estimates)	Contamination Rate[1]	Diversion Rate	Programs/Mandates
Phoenix, AZ	1,513,000	10-20%[2] of material in blue bin recyclables (2013)	18% (2014 estimate)	Two-Tier Collection Pilot Green Organics Collection
Los Angeles, CA	3,884,000	30%[3] of material in blue bin recyclables (2013)	76.4% (2012 estimate)	Recycling and Composting Mandate Three-Tier Collection Educational curriculum Zero Waste city buildings Tax incentives for commercial recycling Incorporating of food waste to green organics program Business Waste Assessment Program Green Business Certification Program for commercial entities Mandate for construction/demolition recycling Partnership with nonprofit donation agency Environmentally Preferred Purchasing Policy for city departments Plastic Bag Ban
Chicago, IL	2,719,000	NA	45% (2009 estimate)	Two-Tier Collection A-Z Recycling Guide Small-scale composting ordinance Residential compost bin rebates Composting workshops Free mail preference service
New York, NY	8,336,697	NA	27% (2013 estimate)	Two-Tier Collection Commercial food mandate City-funded Community Composting Facilities Mayoral "Food Waste Challenge" Drop-off Composting Sites Voluntary food donation programs
San Diego, CA	1,356,000	15% for black bin, 2014 sample study	68% (2012 estimate)[4]	Recycling and Composting Mandates Regulations for Construction recycling Regulations for special event recycling Publications for recycling and composting

[1] It should be noted that contamination rates are less comparable than diversion rates. Some cities in measuring rates take residual rates from municipal MRFs, while others report the figure from bin inspections and sampling. The notion of "contamination" is dependent on how the city processes recyclables and organics.
[2] http://www.recycletogether.com/cities/arizona/phoenix-arizona
[3] http://www.forester.net/pdfs/City_of_LA_Zero_Waste_Progress_Report.pdf
[4] http://www.kpbs.org/news/2013/nov/07/san-diego-considering-zero-waste-initiative/

Dallas, TX	1,258,000	Approximately 16%[5]	40% (2012 estimate)[6]	Two-Tier Collection Educational curriculum Landfill Diversion Program targeting commercial materials
San Francisco, CA	837,442	10-15%[7], for 2014, estimate provided by city staff.	80% (2012 estimate)[8]	Recycling and Composting Mandate Three-Tier Collection Community Recycling Teams Educational Curriculum Zero Waste Curriculum Green Jobs Teams - Outreach Special Events Environmental Preferable Procurement
Seattle, WA	652,405	2009, 6% for single family homes, 8% for multi-family	60% (2012)[9]	Recycling and Composting Mandates Three-Tier Collection Building Salvage/Deconstruction Pilot Projects Residential Backyard composting Edible food recovery from grocery stores and restaurants for feeding programs "Lean Path" analysis for restaurant kitchen efficiency Plastic Bag ban and fee for paper bags Yellow pages opt-out registry Curbside E-Cycle program Community grant program
Portland, OR	609,456	12.6%[10] (2014)	70% (2014)[11]	Community recycling leadership program Three-Tier Collection Educational program credits Community recycling leadership program Plastic Bag Ban Business Recycling Mandate Recycling and Composting public school program
San Jose, CA	998,537	1% for organics, 10% recyclables in 2007	71% (2014)[12]	Two-Tier Collection Green Organics Collection Go Green Schools Program and pilots Environmental Preferable Procurement Extended Producer Responsibility strategies Disposable Packaging Reduction program Private-public partnerships for recycling and composting Home Composting Program Neighborhood Cleanup Program "Green Event" program

[5] Tony O'Sullivan (City of Dallas), December 1, 2014, personal correspondence
[6] http://www.dallascityhall.com/committee_briefings/briefings0812/TEC_LocalSolidWasteMgmtPlan_081412.pdf
[7] Zero Waste Staff (San Francisco), December 1, 2014, personal interview
[8] http://www.sfenvironment.org/news/press-release/mayor-lee-announces-san-francisco-reaches-80-percent-landfill-waste-diversion-leads-all-cities-in-north-america
[9] http://www.seattle.gov/util/groups/public/@spu/@garbage/documents/webcontent/01_026636.pdf
[10] http://www.portlandoregon.gov/bps/article/404493
[11] https://www.portlandoregon.gov/bps/article/496027
[12] http://sanjoseca.gov/DocumentCenter/View/23309

				Educational curriculum
Vancouver (Canada)	603,502	NA	57%	Three- Tier Collection Educational curriculum Red Dot program Extended Producer Responsibility programs Landfill gas management regulations Surplus food recovery programs
Toronto (Canada)	2,791,140	NA	53.3%	Three-Tier Collection Contracted community compost pick-up Business Waste Assessment and Planning support Waste Working Groups Community Environment Days
Flanders Region (Europe)	6,350,765?	NA	75% (2012 estimate)[13]	Three-tier collection Waste Decrees Recycling and composting facility construction Subsidies Required separation of recyclables Landfill restrictions Incinerator and landfill taxes Partnership with local composting NGO Online database of case studies Eco-efficiency assessment program for businesses Educational curriculum Subsidies for second-hand shops Extended Producer Responsibility mandates PAYT Green event assessment and guide Deconstruction requirements for construction projects over 1,000 m^3
Curitiba (Brazil)	1,764,540	NA	70% (2007 estimate)[14]	Three-tier collection Garbage Purchase program The Recycling Station- educational social service site Public outreach electronic displays Educational curriculum

[13] http://www.otherworldsarepossible.org/europes-best-recycling-and-prevention-program
[14] http://www.uwlax.edu/urc/JUR-online/PDF/2007/keuhn.pdf

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