CIRCULAR ECONOMY AND GREEN ORGANIC REGIONALIZATION IN PHOENIX, ARIZONA

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INTRODUCTION

Municipal Solid Waste is at the forefront of the sustainability movement of the 21st century. Sadly, our unsustainable Phoenix has been the topic of books detailing urban sprawl, poor air quality, and poor water management.[1] Added to the list, the Phoenix-Metro region has growing environmental concerns of landfilling, such as methane gas emissions, which led to a rigorous goal to divert 40% from landfills by 2020 as part of the Reimagine Phoenix Initiative. [2]

For solutions, many cities and states are considering the economic, environmental, and social impacts of feedstock aggregation and a circular economy.

The primary purpose of this paper is to determine the economic impacts of feedstock aggregation of waste streams focusing on "residential green organics," and the creation of a circular economy in the Phoenix metropolitan area, as well as, other U.S. metropolitan areas. Our research and analysis also determined the benefits, best practices, and challenges involved with green organic waste and a circular economy which will be presented to city councils, public works departments and private companies as explanation and to support states and cities in the development and successful implementation of related policies.

CURRENT STATE ANALYSIS - PHOENIX

A waste characterization study was completed by the Cascadia Consulting Group in the summer of 2014 to assess the materials going through the Material Recovery Facilities (MRFs). These MRFs only handle single-family homes curbside as well as individual resident drop-offs. It turns out that 40% of the black (refuse) and blue (recycle) bin materials are compostable materials including compostable paper, plastics, and organics[3]. Organics include wood waste and green organics (grass and trimmings from trees and shrubs). If all compostable materials are diverted from the waste stream then Phoenix would meet its diversion goals. Currently, Phoenix does not have a waste sorting system but did start pilot for tan (green organics, not food scraps) cans for residential curbside pickup.

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For every 1 million tons of organic material composted and used locally, almost **1,400 jobs (at $16-20/hr.)** are created each year (ILSR's Waste to Wealth).

LITERATURE REVIEW – CIRCULAR ECONOMY

A circular economy is an economy that is regenerative by design where the two materials flows (a) biological materials, designed to reenter the biosphere, and (b) technical materials, designed to circulate with minimal loss of quality, are ultimately powered by renewable energy (RISN 2014). The four principles of the circular economy are:

- Design for Environment (DfE) to include a variety of nontraditional or less common attributes such as modularity, upgrade-ability, refurbishment, disassembly, re-manufacturing, etc.;
- Industrial ecology or symbiosis, which is based on the premise that the waste from one industrial system or process becomes a resource or material input for another;
- Products of service, whereby a producer retains ownership of a product and leases its utility, taking back the asset at end of useful life or when the lessee no longer wants or needs it; then upgrading, refurbishing or re-manufacturing it into a next generation service-product; and
- Reverse logistics, the process by which products and materials are effectively collected and maintained in a closed loop supply chain [4]

Although a complete circular economy is the ultimate goal, the Resource Innovation Solutions Network (RISN) is most interested in impacts of a circular economy. In order to support the formation of a circular economy, policy makers have the duty to perform a cost benefit analysis for their stakeholders. Our research shows that there are almost no negative aspects to consider when the economic, environmental, and social impacts are reviewed.

Economic Impacts

The list of positive economic impacts is extensive, from business partnerships and industry clusters for supply chain enhancement to job creation through innovation, new businesses, tourism, and capital investment. Positive earnings also come in many forms: sales profit, tax revenues, reduced processing and recycling costs, and branding to attract talent and business. Lastly, resource efficiency (better use and reuse of inputs assures less natural resource use over time) creates value and results in price stabilization, resource security, and risk reduction (Circular Economy: Ellen Macarthur Foundation).

> Nationally, recycling and reuse industries are reported to generate **~$12.9 billion** in federal, state, and local tax revenues (NERC 2009).

Environmental Impacts

The foremost environmental impact of a circular economy is healthier systems from fewer inputs and less waste. When landfills are not being used, there are lower GHG emissions from waste transportation because less hauling and lower levels of methane and other landfill gases from less decomposition. This leads to better air quality, enriched land productivity and soil health, and improved water management (Circular Economy: Ellen Macarthur Foundation).

Social Impacts

The Hanover Principles[1] were developed for the World's Fair in 2000. They are design principles for sustainability and Principle #6 says to eliminate the concept of waste and shift to a more sustainable mindset. A circular economy would certainly perpetuate this principle and be an excellent catalyst for change. Also, community empowerment is important for change. According to Almere Principle #7[2] (defined by international sustainability expert William McDonough), community empowerment results from a circular economy by acknowledging citizens as the driving force in creating, keeping, and sustaining the city.

WHAT SHOULD PHOENIX DO WITH GREEN ORGANICS?

Common end-of-life options for organic waste are Waste-to-Energy (Anaerobic Digestion or Incineration), Waste-to-Products (Mulch, Compost, and Fertilizer), and Landfilling. In support of a circular economy, we recommend composting and anaerobic digestion.

Composting

Compost is the controlled, biological decomposition of organic matter, such as food and yard wastes, into a soil-like material.

There are many *benefits* of compost (EPA 2014):

- Provides nutrients to the soil; reduces the need for chemical fertilizers and pesticides
- Protects soils from erosion and nutrient run-off; alleviates soil compaction
- Assists pollution remediation – captures 99.6% of industrial volatile organic chemicals (VOCs) in contaminated air
- Suppresses certain plant diseases and pest infestations
- Weed prevention & vegetation establishment
- Conserve soil moisture, reduce soil temperature
- Increases beneficial soil organisms (e.g. worms and centipedes)

Every year about **3 million** people worldwide suffer **severe pesticide poisoning** (WHO 2013).

Additionally, the gases emitted from composting can be utilized as a fuel in a second useful life.

"We (the City of Phoenix) need to show is how easy it is and the **benefits of growing your own food**."
– Terry G.

And many *end-users* of compost:

- Large-scale agricultural use
- DOTs (EPA's Program for Compost Use on State Highways)
- Parks Departments – create city contract
- Nurseries & Landscapers
- Big-box home & garden retailers
- Golf courses
- Gardens – home, school, and community

Although we have found that composting is the best way to divert organic waste from the landfill at this stage, we have not found a long-lasting and consistent demand for mulch or compost in the Phoenix-Metro region. An outside market will need to be established. One place to look is the EPA's Program for

[1] http://www.mcdonough.com/wp-content/uploads/2013/03/Hannover-Principles-1992.pdf
[2] http://english.almere.nl/the-city-of-almere/almere-principles/

Compost Use on State Highways where the state Department of Transportation buys the compost made from residential waste to use along the highway system. We also suggest setting up an urban farm/garden partnership for food scraps and composting. This would mean creating incentives like free compost and green waste removal for creating a productive and net-zero carbon space.

Another demand option is the surrounding golf courses in the state of Arizona. Scottsdale alone has over 200 golf courses in the city and surrounding area[5] but when asked about mulch or compost use, many said they might use 1,000-2,000 pounds a year or less, and it must be very high quality.[6] The Phoenix area compost with only landscape waste will not meet high standards because of low nitrogen content, so we suggest a mix with added coffee grounds and food scraps. The addition of food waste keeps the carbon levels at a manageable, on average a 20:1 ratio of Carbon to Nitrogen (C:N) compared to an ideal compost pile with 30:1.[7] For example, cardboard has a C:N ratio of about 350:1, while vegetable scraps are about 10-20:1. On average, the ratio is suggested to be about 30-40% food scraps and other high nitrogen materials like coffee ground, grass clippings, and animal waste.[8]

Feedstock: raw material supplied to a machine or processing plant (e.g. food waste, green organics, plastic, paper, metals, etc.)

Because of the quality issue, and since 28% of the material collected in Phoenix's Municipal Solid Waste (MSW) program is food waste,[9] we recommend these two feedstocks be combined and processed through an anaerobic digestion (AD) system.

Anaerobic Digestion

Up until recently, Anaerobic Digestion has been predominantly used for farm biogas plants, to convert animal waste to electricity through traditional or wet AD. This process converts the biomass into slurry through a pulping process which is water intensive[10]. Recently, dry AD has become prevalent due to the decrease in sensitivity of material entering the process, less water usages, and the creation of compost as a final product.

There are two types of AD that are currently dominating the market in the US, wet and dry AD. Although wet AD is attractive due to low initial capital, it is very water intensive by creating slurry in order to digest the 15% total solids[11]. This means that 85% is water and 15% is the organic compostable solids. In addition to be highly water dependent, this process is also highly sensitive to contamination, a tough factor when working with public participation. On the other hand, dry AD uses 10 times less water than wet AD and creates high quality compost at about the same volume that regular composting would produce.

After extensive research of international and domestic cities, we conclude that the most economical, relevant, and useful methods to divert organic material from the landfill is the dry AD process to create biogas and compost. (Figure 1) We suggest a 5,000 TPY of organic waste input pilot project similar to the Monterey Regional Waste District SMARTGERM® technology through the company Zero Waste Energy, LLC (Figure 2).[12]

Challenges in Phoenix-Metro

- Oleanders – poisonous
- Palm Fronds
- Humidity
- Heat
- Ratio of food to landscape

Zero Waste Energy is leading the dry AD movement in the United States and just opened the largest dry AD facility in the world right in San Jose, California in 2014.[13] This facility currently handles 90,000 tons per year (TPY) of organic waste through compartmentalized dry AD and in-vessel composting of the leftover solids. Although this facility is a great example of how the Phoenix region can scale up at any time, in San Jose the bio gas is used to make electricity through combined heat and power (CHP) process. To reduce biogas processing and harmful emission from CHP, we suggest a better use of the biogas is to fuel waste pick-up trucks. On average, this process will be able to run one standard truck route per 1,000 TPY of biogas created.[14] When this is translated into the TPY that Phoenix is receiving, the city could run 200 trucks for the whole year on the biogas created from AD.

After using a model designed by the Zero Waste Energy team to estimate initial capital costs for implementing a dry AD system we found that it would cost about $3.1 million to start a 5,000 TPY dry AD system in Phoenix (Table 1). In addition to the capital costs to build the AD and composting facility, there is potential to make almost $100 per ton per year on landfill avoidance fees and carbon credits. Taking out the operating costs for the year, there is a potential to make $345,350 per year when looking at these simple calculations.

The Monterey AD facility was built and is being run by Zero Waste Energy which included the capital costs, site and permitting fees and the city only pays the company a $48/ton tipping fee. Zero Waste Energy then creates about $5,000/month in electricity when selling it at $0.12/Kilowatt hour.[15] Although the city would have to pay this tipping fee, it would be a hands-off process that would divert all food and green organics from the landfill as well as either create electricity or fuel for trucks (Table 2).

CHALLENGES AND RECCOMENDATIONS

Challenge	Solution
Logistics and Standardization: Collections, diversion, and contamination are all difficult to manage.	**High-diversion Community:** One that is under private management with exclusive franchise to the local government. These communities have enforceable, mandatory participation but also offer collection of more types of feedstocks, “pay-as-you-throw” fee for refuse, and a flat monthly fee for recycling. For example, the average cost per ton to collect multifamily recycling in the low-diversion group is $177 vs. $113 in the high-diversion group.[16]
Offtake: There is less demand for compost and mulch in the Phoenix area due to the desert climate.	**Market development with pricing structure:** The benefits of compost and users of compost are vast. However, a closed loop must be created with market development with a commodity pricing structure similar to recycled bottles, cans, paper, etc.

Ground Level Ozone: Volatile organic compounds (VOCs) that discharge from compost can influence the Phoenix area to be in "non-attainment" and frequently in violation of EPA requirements.	**Capture all gasses:** Covered or indoor composting with gas capture, or anaerobic digestion systems like SMARTFERM®
Technology: Today's technology is still new and evolving and is sensitive to inputs	**Partnerships and Financing schemes:** Build partnerships and create financial programs to encourage AD technology improvements to accept a larger variety of feedstocks. For example, use grants for technology research and pilot programs, and loans for building infrastructure and market development.
Policy and the Public: Implementation and compliance can be challenging when people are asked to change their behaviors.	**Education and Outreach:** Enact diversion mandates and disposal bans, such as mandating that city departments (e.g. Parks and Recreation) use only city-produced mulch/compost and residential organics collection. Then provide training and educational courses, hold community outreach events, and encourage home composting and gardening

Societal / Mindsets

> "We (the City of Phoenix) have been selling thousands of composters for only $5 each for at least 20 years. With that gives us an opportunity to educate on how to use them. We might have these, but not many come and those that do, they don't last long as gardening takes patience and time...which our society doesn't do well yet. That's what we need to show is how easy it is and the benefits of growing your own food."

CONCLUSION

Keeping in mind the rigorous diversions goals set by the city of Phoenix, we recommend starting a pilot dry anaerobic digester project for combined food and green waste. Consideration should be made for a varied range and composition of feedstocks throughout the year. For example, tree limb tonnage may be highest during monsoon seasons and will be wetter than the summer tree limbs. Monitoring this is important to gain an understanding of the city before creating a huge AD network.

Furthermore, we do recommend consolidating the collection of green organics to one or two locations throughout the region. This would increase vehicle miles travels and fuel usage, decrease the access of compost to locals, and decrease the number local of jobs created. With the system we recommend, ZWE Dry AD facilities have 40ft long by 12ft wide by 8.5ft tall digesters that process about 1,250 TPY. This amount of tons can be split into sister facilities scattered into each town due to the fact that it is a non-continuous and compartmentalized process.

However, we do recommend regionalization of feedstock, which is a regional systems approach, for the Phoenix-Metro area to create market demand for products, take advantage of economies of scale, and provide consistent messaging for residents and participants valley-wide.

Next Steps:

- Pilot dry AD project to understand the ratio of food to landscape waste (5,000 TPY)
- Continue composting the rest of the green organics and mix in food waste
- Work with golf courses to create high-quality compost
- Promote local urban gardens
- Develop food waste curb-collection program
- Implement policy to ban organic waste from the landfill
- Collect data on avoidance savings (e.g. cleaner air from less hauling and decomposition

APPENDIX

Solution	Soft Approach	Strong Approach
Eco-design	Recommend use of “preferred” plants	Mandate plant use
Landfilling	Incentive for greeen dumping	Fines for mis-dumping
Change Framework	Education and communtiy outreach, voluntary participation	Mandatory participation

Figure 1: Dry Anaerobic Digestion Process[17]

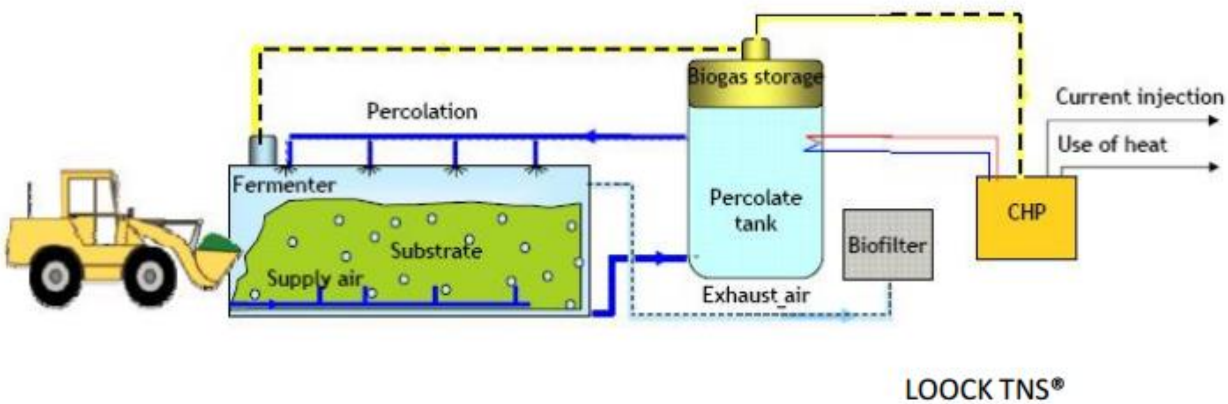

Figure 2: SMARTFERM® system process to create compost and electric power[18]

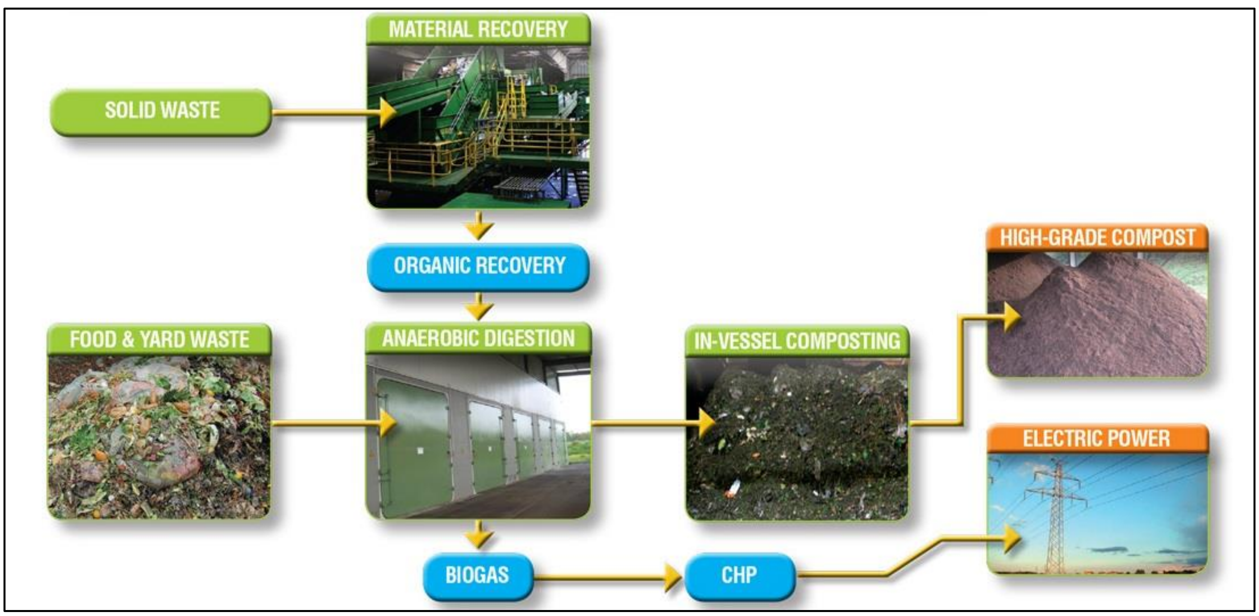

Table 1: Example calculations to start and run a system similar to Zero Waste Energy Dry AD plant. This information was extrapolated from Zero Waste Energy Financial Return spreadsheet[19]

Revenue opportunities	**5 Digester Concrete 25,000 TPY**	**$/ton**
Biogas Upgrade ($2.25/DGE) 298,981 DGE for 5 concrete digesters	$ 672,707.25	$ 26.91
Digestive composting after processing ($10/ton at 90%)	$ 225,000.00	$ 9.00
Carbon Credits @ $12.47/MTCO2 or $2.94/inbound ton	$ 73,535.71	$ 2.94
Renewable Identification Number (RINs) @ $.80/RIN or $1.35/DGE	$ 402,264.80	$ 16.09
Operating and SG&A Costs		
Transportation and Disposal of Residual	$ -	$ -
Labor (equipment operators, PT Mechanic and Laborers)	$ 66,937.00	$ 2.68
Equipment variable (PMs, routine maintenance, equipment ops and consumables)	$ 186,345.00	$ 7.45
Utilities, Indirect, and Operations Support	$ 255,250.00	$ 10.21
Selling, General, and Administrative	$ 63,329.00	$ 2.53
SMARTFERM Capital Costs		
Systems Design, Permitting Support and Engineering	$ 445,000.00	$ 17.80
Base SMARTFERM Technically Package and Civil Construction	$ 6,689,227.00	$ 267.57
Biogas Upgrading System	$ 1,970,207.00	$ 78.81
SMARTFERM Installation	$ 661,111.00	$ 26.44
STARTFERM Start-up and Performance Testing	$ 113,000.00	$ 4.52
Total SMARTFERM Capital Costs	$ 9,878,545.00	$ 395.14
Composting System		
Aeration Bay/Receiving Bay/Mixing Hall	$ 395,000.00	$ 15.80
In Vessel Composting (Ammonia Scrub)	$ 894,832.00	$ 35.79
In Vessel composing (capital)	$ 4,474,160.00	$ 178.97
Total Composting Capital Costs	$ 5,763,992.00	$ 230.56

Table 2: Monterey Regional Waste Management District Dry AD Specs[20]

SMARTFERM AD Process	Results
Annual Volume	Up to 5,000 TPY
Digester Dimensions	40' (L) x 12' (W)
Steel Digesters	4
Residence Time	21 Days
Mode of Operation	Thermophilic (125-131°F)
Biogas Yield (CF/Ton)	3,000 - 3,200
Methane Content (%)	58 - 60
Electrical Output	100 kW
Finished Compost @ 40% Moisture Content	2,200 TPY
Total Diversion	+99%

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