How the US Economy and Environment can Both Benefit From Composting Management

Authors: Farhidi, Faraz, Madani, Kaveh, and Crichton, Rohan

Source: Environmental Health Insights, 16(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/11786302221128454

How the US Economy and Environment can Both Benefit From Composting Management

Environmental Health Insights
Volume 16: 1–6

Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/11786302221128454
SAGE

Faraz Farhidi[1], Kaveh Madani[2] and Rohan Crichton[3]

[1]NV Energy, Las Vegas, NV, USA. [2]Institute for Integrated Management of Material Fluxes and of Resources, United Nations University (UNUFLORES), Dresden, Germany. [3]David Reh School of Business, Clarkson University, Potsdam, NY, USA.

ABSTRACT: Composting is one of the environmentally friendly ways of reducing organic waste. It is economically viable since it cuts costs associated with the hauling of wastes and enables farmers to reduce the use of fertilizers. Composting operations are relatively non-existent in the solid municipal waste sector, as the market has molded itself and grown into a standard "bury-or-burn" model. As humans are trying to address global warming, composting proves to be a promising climate change mitigation option, benefiting societies in terms of the environment, the economy, and overall health. This study projects that—with the current trends—by the end of 2030, the U.S. can increase the compost to waste ratio by 18% from 10%, reducing carbon emissions by 30 million tons a year while saving around 16 billion USD in municipal waste management costs. Analyzing the existing records in the OECD countries suggests that economic motives are not powerful enough to incentivize the industry/household toward composting. Stricter environmental policies can boost the composting volume by 214-574 thousand tons per year. Imposing waste taxes and penalties can give birth to a vast industry that has not yet flourished while the economic subsidies financed by the collected taxes and penalties can incentivize the private sector to further invest in composting.

KEYWORDS: Carbon reduction, composting, environmental policies, food nutrition, waste management

RECEIVED: April 6, 2022. **ACCEPTED:** August 27, 2022.

TYPE: Perspective

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Faraz Farhidi, Senior Quantitative Analyst, NV Energy, Las Vegas, NV 89135, USA. Email: faraz.farhidi@nvenergy.com

Introduction

The debate on the trade-off between sustainability and economic growth has been going on for decades.[1] The typical presumption is that societies need to incur financial losses to protect the environment. By focusing on waste composting as an example, this article argues that not only environmental protection and economic growth can co-exist, but also the former can boost the latter. Composting is one of (possibly) many environmentally friendly activities that human societies can benefit from. Food waste and improper handling of organic waste matter is a huge problem worldwide and most severe in certain parts of the world like the United States.[2] Americans produce an average of 2 kg of solid trash every day.[3] Of all the solid waste sent to landfills or incinerators, between 18% and 40% are food, yard trimmings, and other organic materials.[4] When a landfill is being capped, the land is severely limited in its perspective functions.

It is also important to note that capping a landfill cost-effectively and correctly to prevent any leachate and runoff is complex and rarely achievable.[5] Among the sources vulnerable to leachate contamination are groundwater, rivers and streams, wetlands, and the soil used for agricultural purposes. More than 2 billion tons of biodegradable agro-waste are produced worldwide every year,[6] which will increase by 70% by 2050.[7] Thus, Agricultural composting is another major problem that needs attention. Agro-biowaste compost can be engineered to reduce its environmental impact. There are strategies such as pelletizing dying that could mitigate the weighted environmental impact of farm compost by more than 63%.[8] Alternatively, part of the potential compost waste can be diverted to biomass conservation units, promoting environmental sustainability, and producing energy that otherwise would be wasted and converted directly to greenhouse gases (GHGs).[9] While it is well-understood that more than half of the accumulated GHGs in industrialized countries come from fossil energy,[10] the ongoing debates must extend to the other sources of emissions such as waste due to the invaluable opportunities they provide for GHG mitigation.

An Overlooked Opportunity

Pollution

Every year, 227 billion kilograms of trash are being sent to landfills and incinerators in the United States.[6] More than one-third of this municipal solid waste is compostable such as food scraps, paper and paper products, yard trimmings, and wood waste. Food waste is omnipresent. It represents one-third of all the food harvested and produced per year. Globally, it has a larger carbon footprint (3 billion metric tons of CO_2-equivalent per year) than the yearly national footprint of every country except for the U.S. and China.[a] Composting can significantly reduce soil contamination, cut carbon emissions, and improve human health and the environment.

Both landfilling and incinerating are significantly harmful to the environment and the people living in their vicinity.

The most harmed groups of people are usually the lower-income families living in disadvantaged communities, without sufficient resources to mitigate or adapt to the resulting health hazards. One of the most severe and damaging products of landfilling trash is the GHGs released from the anaerobic decomposition of organic wastes. Food piled in a landfill does not have access to oxygen, which is one of the preconditions of environmentally-friendly biodegrading during composting. Organic scraps decomposing anaerobically produce carbon dioxide (CO_2) and methane. Methane is the third most potent GHG, with a Global Warming Potential (GWP) score of about 36 over 100 years,[b] which means methane absorbs much more energy than CO_2. It traps more heat, increasing global warming. Methane is also a precursor to ozone, another harmful GHG, and stays in the atmosphere longer than CO_2.

Incinerators also contribute to GHG emissions and other various harmful pollutions. These facilities burn all the trash and release polluting gases such as CO_2, mercury, and polycyclic aromatic hydrocarbons (PAHs) as well as particulate matter (PM) into the air. It has been found that 29% of worldwide human-caused PM emissions in the air come from burning trash.[11] it is also estimated that trash incineration is responsible for 10% of all mercury emissions and 40% of PAHs.[11] For every ton of solid food waste left in a landfill, 0.75 tons of CO_2 equivalent are created in methane.[12] The United States is the largest emitter of landfill GHG, producing 143 million tons of CO_2 equivalent every year, significantly higher than the most populous country of the world, China, which is the second-largest emitter with52 million tons of CO_2-equivalent per year from landfills.[13]

The GHG produced by composting a ton of waste is less than 10% of that of landfilling, it.[14] Replacing landfilling with composting is an effective strategy for the United States to address its growing pollution problem. But a drastic transition from landfills to composting is impossible overnight. So, the main policy question is how fast society can transition to composting to begin enjoying its many benefits. Composting the 152 billion kilograms of food waste in the United States every year instead of sending them to landfills leads to a reduction of 128.7 million tons of CO_2-equivalent emitted. If every gram of solid waste were composted nationwide, only 14.3 million tons of GHG would have been emitted throughout the process, compared to 143 million tons of GHG that is being produced today. This could have reduced U.S. carbon emissions by 2.5%. Redirecting 50% of the 152 billion kilograms of food waste, current sent to landfills, to the compost facilities results decreasing US GHG emissions by 64.35 million tons of CO_2-equivalent. That means that if every single gram of solid waste were composted nationwide, only 78.65 million tons of CO_2-equivalent would have been emitted throughout the process, compared to the 143 million tons that are being released today.

Nutritious

Modern-day agricultural practices and standards are detrimental to the environment and human health. Large-scale farming depletes the soils. As commercial farmers harvest massive batches of crops, year after year, soil nutrients are removed and become unavailable to future harvests. Generally, decomposed plants, food material, and organic waste are the sources of soil nutrients. The top layer of soil (topsoil) is supposed to be nutrient-rich, as this is the main layer that plants come in contact with. One-third of the world's topsoil is being degraded, and the current farming practices deplete the topsoil in the U.S. at 9 times the natural soil replacement rate.[15] Farming in nutrient-deprived soil leads to producing nutrient-depleted food that is at high risk of being contaminated. Systematic large-scale farming creates more crops than the land can naturally produce, depleting the soil. So, the current agricultural practices broadly incorporate manure and other sewage as soil amendments. Farmers often turn to waste and sewage sludge containing some nutrients in different forms and abundances to mitigate soil depletion.[16] Sewage sludge is popular across the U.S., resulting in toxins reaching various waterways and aquatic ecosystems. In the long run, sewage sludge and pollutants both decrease the growth and flourishment of all plants that may come into contact with it. Davis et al[17] suggested that the decline in the U.S. food nutrient could be explained by the changes in cultivation methods between 1950 and 1999. On the other hand, Marles[18] believes that the decline in mineral nutrient composition has been compensated by intensive cultivation using chemical fertilizers.

Khiatah[19] found that nitrosamine (a standard component of chemical fertilizers) contributes to Alzheimer's disease, diabetes mellitus, non-alcoholic steatohepatitis, DNA damage, oxidative stress, lipid peroxidation, and pro-inflammatory cytokine activation—which together led to increased cellular degeneration and death. These additional uncalculated health costs related to food production could be curbed with composted soil to fertilize crops organically. In 2014, the U.S. used approximately 21 billion kilograms of commercial fertilizer. This amount of fertilizer could gradually be replaced with compost. Replacing fertilizer with clean compost drastically reduces the negative externalities of using commercial fertilizer while adding all the positive externalities associated with compost.

Soil depletion also affects the quality of agricultural products. Jack[20] compared an assortment of 12 vegetables in 1975 to the same mixture in 1997. This study found that the Calcium, Iron, Vitamin A, and Vitamin C contents of these vegetables had decreased by more than 20%. In a later study, Esther[21] reported that the Calcium, Iron, and Potassium contents of vegetables in the U.S. had decreased by 19%, 22%, and 14%, respectively from 1930 to 1980.

Table 1. Impacts of environmental policies and different types of technologies on composting. The primary explanatory variable is EPS (environmental policy stringency: ranging from 0.2 to 4.1) and the dependent variable is composting (ranging from 0 to 24485 thousand tons).

	COMPOSTING VOLUME IN MILLION TONS				
	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
EPS (environmental policy stringency)	214.0** (93.5)	572.4*** (209.9)	547.1** (216.4)	573.7*** (210.7)	570.9*** (205.4)
Environmental tech*	–	−1.653 (1.485)	–	–	–
Handling tech	–	–	1.740 (1.640)	–	–
Machinery tech	–	–	–	2.512* (1.405)	–
Chemical tech	–	–	–	–	−3.173*** (1.151)
Controls**	Yes	Yes	Yes	Yes	Yes
Country and time FE***	Yes	Yes	Yes	Yes	Yes
N	367	115	115	115	115

*Technology-specific advancement is available since 2008, while the other data exist from 1990.
**GDP, energy consumption, number of patents, population, recycling, yearly trend are included as the control variables to decrease the biases due to omitted variables.
***Fixed effect (FE) panel model was used in this analysis.
Standard errors in parentheses.
*$P < .1$. **$P < .05$. ***$P < .01$.

Organic waste can naturally be composted by combining carbon-rich organic material with nitrogen-rich organic material. By combining organic wastes and ensuring adequate oxygen and moisture retention, bacteria begin to biodegrade the materials. These bacteria start feeding and reproducing rapidly, generating much heat between 49°C and 71°C. This heat is generated constantly for 2 to 4 months. During this period the high temperature kills all harmful pathogens, weed seeds, insects, and their eggs. When done correctly, a compost pile will turn its contained waste into clean, fertile, and nutrient-rich soil, replacing commercial fertilizer and reducing the carbon footprint of fertilizer production, leading to a higher quality of the products.

Economy

Composting production is also associated with major socio-economic benefits. On a per-ton basis, composting operations in Maryland employ twice as many people as landfilling and 4 times more than trash incinerator facilities.[22] According to Platt et al,[23] for every 10 million USD invested, composting facilities in the United States supported twice as many jobs as landfills and seventeen times more than incinerators. Assuming composting can divert 30% of the average waste incinerated, the same study concludes that a saving of 60 USD can be achieved per one ton of composted waste. Beattie[24] showed that compositing was economical since it helped individuals cut waste hauling fees by 700 USD per ton (on average), assuming a composting cost of 280 USD per ton. New composting operations generate numerous jobs for people at different parts of the composting process such as drivers, processors, supervisors, manual laborers, administrative staff, inspectors, scientists, and technicians. Additional positive effects directly correlated with compost application are filtering heavy metals from groundwater, water conservation in agriculture, and reduced environmental degradation.

The externalities of food waste come in many forms. These include, but are not limited to the water, energy, and chemicals/fertilizer used in production, space occupied by landfills, the generated pollution during production, which is approximately 1.1 billion tons of CO_2-equivalent, and the health risks associated with chemical fertilizers compared to composted soil/fertilizer. The amount of food produced and wasted in 2019 was equivalent to 1.3 billion tons, 1 TUSD in economic costs, approximately 700 BUSD in environmental costs, and 900 BUSD in social costs.[25]

Environmental policies and adopted composting technologies

We used a basic panel fixed effect model using 39 OECD countries to evaluate the relationship between composting d environmental policies. Table 1 shows the impact of environmental policies on composting and the adopted technologies in the OECD countries. Environmental policies (evaluated based on the environmental policy stringency index, EPS) positively affect composting in all scenarios (including and excluding different technologies); while it has been shown that as waste generation escalates, policymakers tend to make stricter policies to control it (Farhidi et al).[26] Results suggest that, when EPS index increases by one unit (almost 25% rise, which means nations make severer environmental policies), the total volume of composting increases by 214 thousand tons per year. This amount rises to 570 thousand tons per year when technological advancements are taken into account. This implies that when a

Table 2. Acronyms used in the text.

ABBREVIATIONS	UNIT/RANGE	DESCRIPTION
EPS	0.2–4.13	Environmental policy stringency
GHG	Tons	Green house gases
CO_2	Tons	Cabon dioxide emission
GDP	USD ($)	Gross domestic prodduct
OECD	Countries	The organization for economic cooperation and development
GWP	Score	Global Warming Potential
PM	Micron	Particulate matter
MUSD	$	Million United States dollar
BUSD	$	Billion United States dollar
TUSD	$	Trillion United States dollar

relevant control variable is added—technological progress in our case—, not only did not weaken the positive relationship between environmental policy and composting, but also strengthen it. Technological impact on composting is positive in case of handling, and machinery advancements, but not for the patents registered in the chemical domain. Not surprisingly, there exist positive correlations between composting and GDP, energy, number of patents, and recycling—, while population has negative impacts on composting. Table 2 show the acronyms used in the text.

An Untapped Potential

Over 6 million Americans participated in food composting in 2017.[27] Over 5 million households in approximately 18 U.S. States have access to curbside compost collection services in 2017. Between 2007 and 2012, the number of these households increased by 239%.[28] In 2015, Americans turned 23 million tons of municipal solid waste into compost. Conservatively assuming organic waste to be only 30% of the total amount of waste produced by the Americans nationwide (about 268 million tons in 2018), by implementing nationwide composting programs and food waste penalties, 80 million tons of organic waste can be diverted from landfills and incinerators to composting. Assuming that the organic content of the U.S. waste is 60% rather than 30%, 161 million tons of waste can be diverted from landfills through composting.

Every year, 35 million tons of food scraps, 14 million tons of yard trimmings, 13 million tons of ruined paper, and 13 million tons of wood squander are scorched or sent to landfills from America's metropolitan waste streams. If only 50% of the paper and timber squander were compostable, 62 million tons of waste could have been turned to soil, leading to producing 21 million tons of manure.

San Francisco could be a role model among the U.S. cities that turn food waste into nutrient-rich and profitable compost. Researchers and advocates of the city's recycling and composting ordinance state that the compost made from municipal waste helps farmers survive drought and sequester carbon from the atmosphere.[29] San Francisco avoids sending a quarter-million kilograms of organic waste to landfills every year. It successfully diverted 80% of its waste away from landfills since the program has started in 2003. In 2020, this Californian city set the new goal of avoiding 97% of its landfill waste by 2030.

Future Trend

Figure 1 shows the expected amount of composted waste in the United States till 2030, based on the current growth rate. Gross domestic product (GDP), energy consumption, population, unemployment, number of the patents, and carbon emissions were taken into account. A multi-step method was used to project the future composting trends in the United States. First, population change was estimated based on the current population growth trend in the United Stated. Next, the existing trends in inflation, future inflation and unemployment rates were estimated. Using these values, the expected GDP and energy use were projected. Then, through a similar process, the patents trend was estimated in order to calculate the carbon emissions and total waste generation. Finally, the estimated variables (and their lags) were used to project the total composting volume in the future.

The current compost to waste ratio in the U.S. is around 10%, expected to rise to 18% by 2030. The 8% increase will turn an additional 23 million tons of waste into compost, reducing carbon emissions by 30 million tons of CO_2 equivalent, leading to a cost saving of 16.1 billion dollars, and creating 8 to 12 thousand jobs. Although these projections are not accurate, underline the fact that environmental conservation can boost economic growth, rather than limiting it. So, increasing investments in composting results in the creation of more jobs, carbon emissions reduction, major waste management

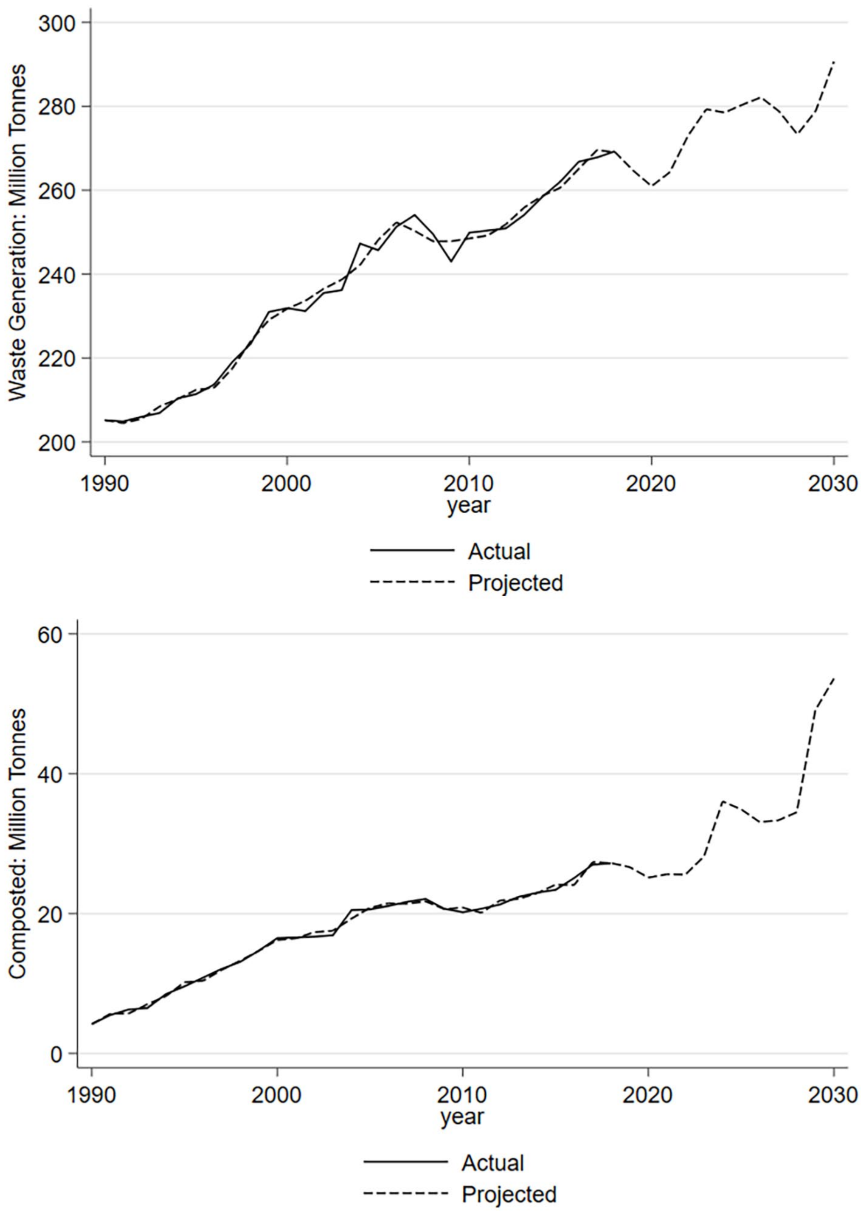

Figure 1. Projected waste generation (upper panel) and compost (lower panel) in the U.S. by 2030.

cost savings, improvement of the quality and nutrition value of agricultural products, and reduction in the use of commercial fertilizers which overall improve human/environmental health and the quality of life.

Acknowledgements

We want to thank Yazdan Navabi for his research and inputs on composting data.

NOTE

a. The food supply chain annually produces around 3 billion metric tons of CO_2-equivalent where this amount for the US and China is 5.5 and 10 billion, respectively.
b. GWP is a measure of how much energy emissions will be absorbed by 1 ton of gas over a while, relative to one ton of CO_2.

REFERENCES

1. Toman MA. Economics and “sustainability”: balancing trade-offs and imperatives. *Land Econ*. 1994;70:399-413.
2. Warshawsky DN. Food waste, sustainability, and the corporate sector: case study of a US food company. *Geogr J*. 2016;182:384-394.
3. EPA. National overview: facts and figures on materials, wastes and recycling. 2018. Accessed October 2019. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#:~:text=The%20total%20generation%20of%20municipal,25%20million%20tons%20were%20composted
4. Goldstein N. State of composting in the U.S. *BioCycle*. July 16, 2014. Accessed October 2019. https://www.biocycle.net/2014/07/16/state-of-composting-in-the-u-s/
5. Simon FG, Müller WW. Standard and alternative landfill capping design in Germany. *Environ Sci Policy*. 2004;7:277-290.
6. De Corato U. Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: a review under the perspective of a circular economy. *Sci Total Environ*. 2020;738:139840.
7. Hamedani SR, Colantoni A, Gallucci F, et al. Comparative energy and environmental analysis of agro-pellet production from orchard woody biomass. *Biomass Bioenergy*. 2019;129:105334.

8. Sarlaki E, Kermani AM, Kianmehr MH, et al. Improving sustainability and mitigating environmental impacts of agro-biowaste compost fertilizer by pelletizing-drying. *Environ Pollut*. 2021;285:117412.
9. Shahbeig H, Shafizadeh A, Rosen MA, et al. Exergy sustainability analysis of biomass gasification: a critical review. *Biofuel Res J*. 2022;9:1592-1607.
10. Crichton R, Farhidi F, Patel A, et al. Clearing up the benefits of a fossil fuel sector diversified board: a climate change mitigation strategy. *Bus Soc Rev*. 2021;126:433-453.
11. Thompson A. Burning trash bad for humans and global warming. 2014. Accessed September 2, 2014. https://www.scientificamerican.com/article/burning-trash-bad-for-humans-and-global-warming/
12. Brown S. Connections: CO2 math for food waste transport. 2014. Accessed May 8,2020.https://www.biocycle.net/2013/08/01/connection-co2-math-for-food-waste-transport/
13. Gies E.Landfills have a huge greenhouse gas problem. Here's what we can do about it. 2016. Accessed May 8, 2020. https://ensia.com/features/methane-landfills/
14. Deesing B. Comparing greenhouse gases from composting and landfilling. Proceedings of the National Conference on Undergraduate Research (NCUR), University of North Carolina at Asheville, 7-9 April, 2016. Asheville; NC; 2016.
15. Risse ML, Faucette B. Compost utilization for erosion control. 2015. Accessed October 2019. https://extension.uga.edu/publications/detail.html?number=B1200&title=CompostUtilizationforErosionControl
16. Louwagie G, Gay SH, Sammeth F, et al. The potential of European Union policies to address soil degradation in agriculture. *Land Degrad Dev*. 2011;22:5-17.
17. Davis DR, Epp MD, Riordan HD. Changes in USDA food composition data for 43 garden crops, 1950 to 1999. *J Am Coll Nutr*. 2004;23:669-682.
18. Marles RJ. Mineral nutrient composition of vegetables, fruits and grains: the context of reports of apparent historical declines. *J Food Compost Anal*. 2017;56:93-103.
19. Khiatah B. The health impacts of chemical fertilizers. *Amos Institute*. 2018. Accessed October 2019. https://amosinstitute.com/blog/the-health-impacts-of-chemical-fertilizers/
20. Jack A. Nutrition under siege. *One Peaceful World*. 1998;34:1-8.
21. Esther G. Dirt poor: have fruits and vegetables become less nutritious?. 2011. Accessed October 2019. https://www.scientificamerican.com/article/soil-depletion-and-nutrition-loss/
22. Kunze J. 60 organizations sign on to move Maryland from trash incineration to zero waste. 2020. Accessed June 2021. https://www.cleanwateraction.org/2020/02/17/60-organizations-sign-move-maryland-trash-incineration-zero-waste#:~:text=On%20a%20per%2Dcapital%2Dinvestment,zero%2Dwaste%20economy%20in%20Maryland
23. Platt B, Lombardi E, Ciplet D. Stop trashing the climate. Full Report; 2008. Institute for Local Self-Reliance. Accessed June 5, 2008.
24. Beattie A. Cost-benefit analysis of food-waste composting program at UMM, Scholarly Horizons: University of Minnesota, Morris Undergraduate Journal, 2014;(1) 1.
25. USDA. Why should we care about food waste? Accessed June 2020. https://www.usda.gov/foodlossandwaste/why
26. Farhidi F, Madani K, Crichton R. Have extreme events awakened us? *Sustainability*. 2022;14(12):7417.
27. EPA. Reducing the Impact of Wasted Food by Feeding the Soil and Composting. Accessed June 2020. https://www.epa.gov/sustainable-management-food/reducing-impact-wasted-food-feeding-soil-and-composting
28. Platt B, Streeter V. Residential food waste collection access in the U.S. *BioCycle*. December 6, 2017. Accessed November 2019. https://www.biocycle.net/subscriber-exclusive-residential-food-waste-collection-access-u-s-complete-report/
29. McClellan J. How San Francisco's mandatory composting laws turn food waste into profit. *Azcentral*. 2017. https://www.azcentral.com/story/entertainment/dining/food-waste/2017/08/03/san-francisco-mandatory-composting-law-turns-food-waste-money/440879001/