Town of Dennis Guidelines and Case Study for Forecasting Municipal Solid Waste

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EE538: Research for Environmental Organizations and Agencies

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April 29th, 2023

Introduction:

The production of waste is a natural consequence of consumption. It cannot be avoided as we go about our daily lives. However in recent decades, economic and population growth, changes in consumer behavior, and the process of urbanization have all contributed to an increase in solid waste generation worldwide (Izquierdo-Horna et al. 2022). Municipal Solid Waste (MSW) is strictly defined as materials that are discarded from residential and commercial sources (Vergara and Tchobanoglous, 2012). In a report from the United Nations Environment Programme, MSW generation reached 2.3 billion tonnes in 2023 and is expected to grow to 3.8 billion tonnes by 2050. Along with the issue of managing increased waste output, city governments are challenged with increasing waste disposal fees, greater market demands for education, public health, and a lack of local landfill and incineration options (Izquierdo-Horna et al. 2022). Because of these challenges, towns across America are looking to implement policies that can help reduce their waste tonnage.

To inform these policies, the ability to contextualize waste streams and forecast them becomes especially important. Understanding how and where our waste comes from, and how our waste is forecasted to change in the future is the cornerstone of developing the most effective policies and strategies to manage our waste. In general, Municipal Solid Waste is made up of organics, paper, plastic, metal, glass, electronics, C&D, and HHW (SAK Environmental 2023). These different types of MSW can have different environmental and health impacts due to the nature of the material, and the disposal method (Eriksson et al, 2005).

Currently, many towns across the US are looking to collect more information on their waste production and create innovative solutions to mitigate their municipal solid waste. In the Town of Dennis, Massachusetts, actions and policies such as home composting challenges, ban of single-use plastic water bottles, and the creation of an app to help inform visitors and residents where they can recycle their goods, have been implemented in order to reduce their waste (Town of Dennis). However, in order to continue their goal, the Town of Dennis seeks to more closely understand its waste production, and looks to forecast that production into the future to take preemptive measures in meeting their waste goals.

Thus, in order to help the Town of Dennis meet their goals, I analyzed local Cape Cod waste generation from the past 14 years with the help of experts to better understand waste trends. By contextualizing these trends from the past, I hoped to gain insight into how waste may change in the future and what factors may affect that change. With this research and analysis, it was possible to develop a guideline to assist towns such as Dennis in forecasting their municipal solid waste. Along with this guideline, insights from my research revealed some potential actions that towns can take in order to reduce their waste output.

Section 1: SEMASS Data

As part of the Class II Recycling Program, combustion facilities in the state of Massachusetts are required to conduct a waste characterization study within 18 months of receiving their certification and every three years thereafter. SAK Environmental, a municipal solid waste consultant company, conducted these evaluations for the Southeastern Massachusetts Resource Recovery Facility (SEMASS) for the past 14 years. This facility, located in West Wareham, Massachusetts, provides over 50 communities in southeastern Massachusetts and Cape Cod, including the Town of Dennis, with a means of disposing of MSW (SAK Environmental 2023). In order to contextualize how Dennis' waste production may be changing, we visualized this data and elicited expert opinion to help extrapolate information from this data set that could then be used in the Town of Dennis' decision making processes regarding their waste management. Contextualization of the data set was conducted with the assistance of Kari Parcell, the Massachusetts' Southeast District 1 Municipal Assistance Coordinator.

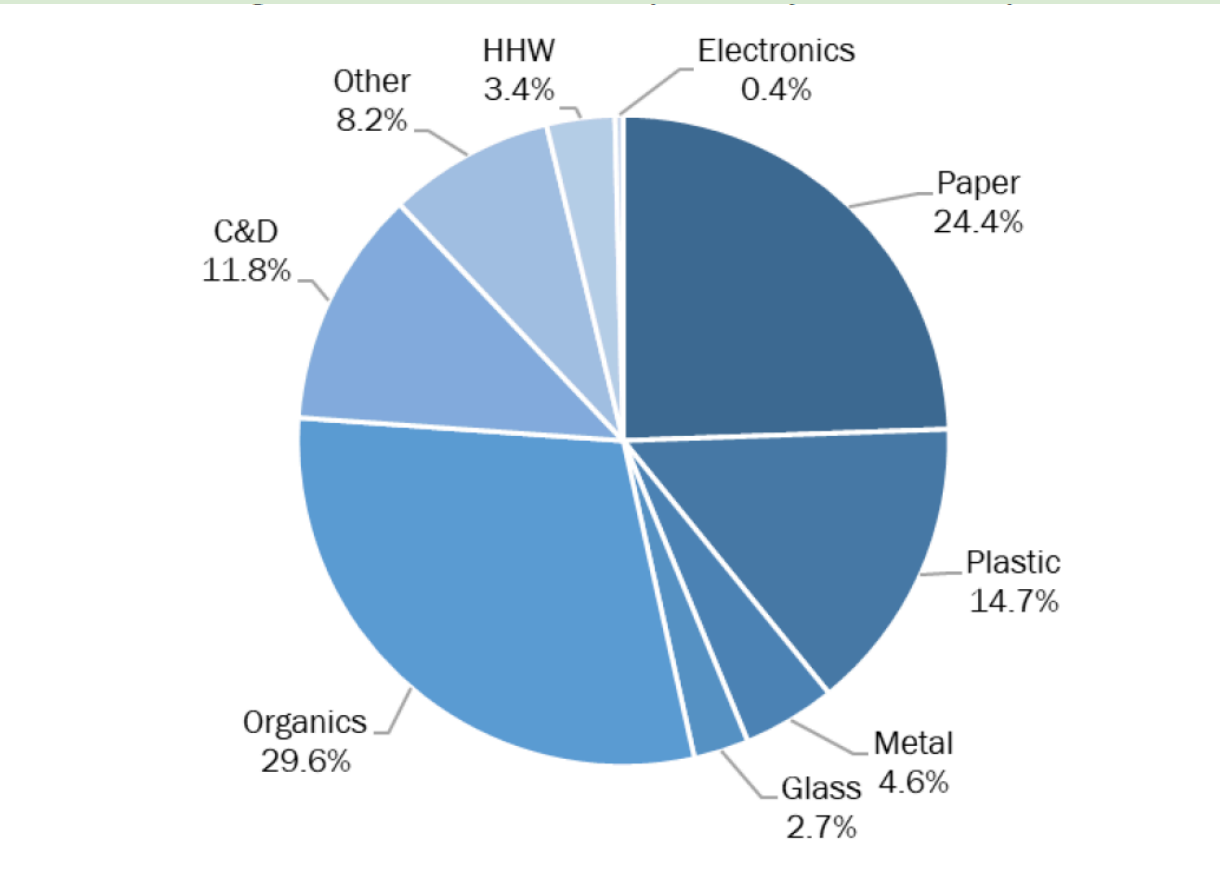

Figure 1: Overall Waste Composition by Material Group

Based on the 2022 Covanta report, the largest categories of waste that the SEMASS facility processed include, by order, organics, paper, and plastic. Thus, for our analysis, we focused on waste streams within these specified categories, including waxed cardboard, PET plastic, compostable paper, film, food waste, and aggregate plastic.

Waxed Cardboard:

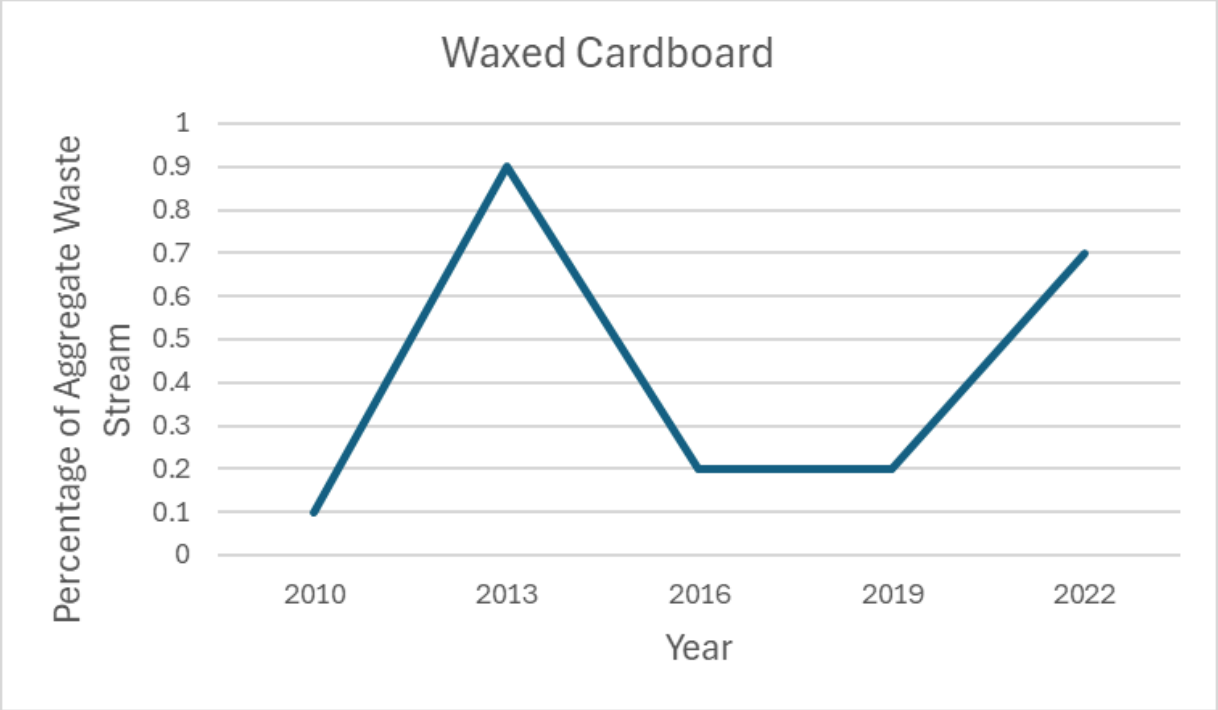

Figure 2: Pattern of waxed cardboard as percentage of total aggregate waste stream from 2010 to 2022.

From this figure, it is clear that waxed board makes up a very volatile portion of the aggregate waste stream. In 2010, its composition of total aggregate waste was small, but spiked in 2013 and then declined again in 2016 through 2019. Waxed cardboard, while a product primarily made of paper, is not often accepted by recycling facilities. Recycling infrastructure is primarily made up of local vendors, and Materials Recovery Facilities (MRFS) serve as the majority of these vendors. Because they are privately owned, MRFs are given a lot of flexibility in what types of materials they can reject. Often, they do not accept waxed board because it is contaminated with materials that can interfere with the recycling process. Waxed board is a primary example of the connection between recycling and market fluctuations. Because waxed cardboard is difficult to process, it has to be valued in the recycling market for MRFs to be willing to accept the material and pull it out of the waste stream.

PET Plastic:

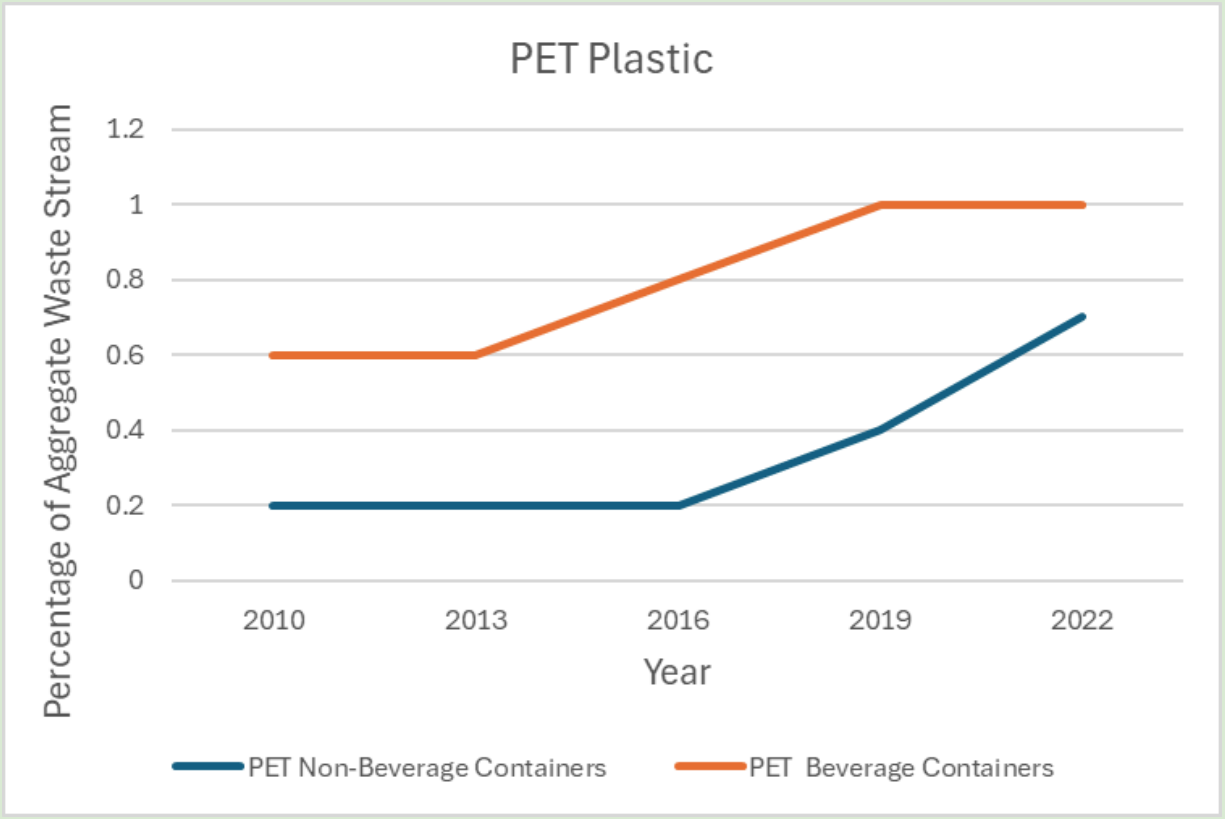

Figure 3: Pattern of PET non-beverage and beverage containers as percentage of total aggregate waste stream from 2010 to 2022

Unlike waxed board, PET plastic containers show a steadily increasing trend rather than large fluctuations. PET is a commonly found plastic because it is food safe. Here, we observe that people are disposing of more plastic in 2019 and 2022. One of the possible driving forces behind this change is the restaurant adoption of the takeout model as a result of the Covid-19 pandemic in 2020 when quarantine prohibited people from eating at restaurants. As a result of increased takeout, people are using more plastic bags, forks, knives, etc.

Compostable Paper:

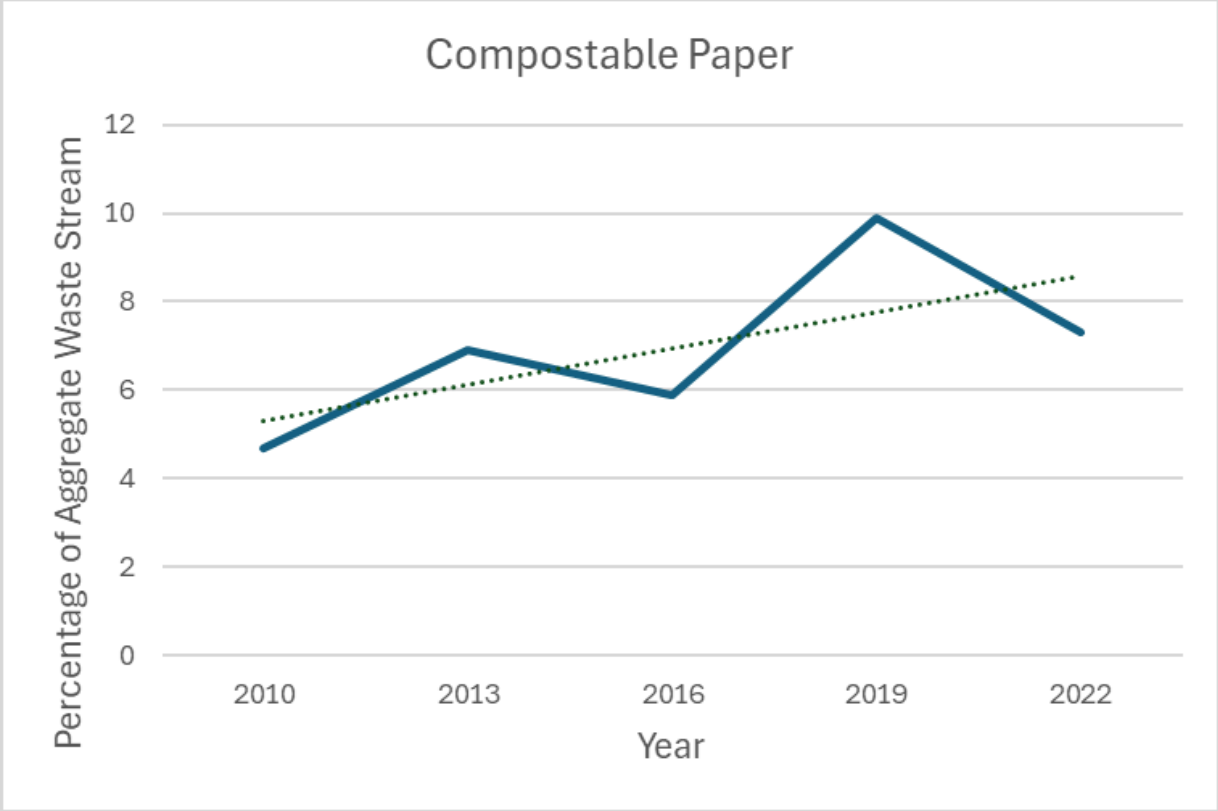

Figure 4: Pattern of compostable paper as total aggregate waste stream from 2010 to 2022.

In fitting a trend line to this graph, it is clear that compostable paper has ultimately increased within the waste stream since 2010. This increase is primarily due to the popularity of compostable goods as an environmentally friendly alternative to traditional products. Because of this, many industries are switching to compostable paper because of its "environmentally friendly" classification. However, because this paper is ending up back in the landfill, it cannot break down the way it was actually meant to break down. Specifically in the cape code area, there is a lack of industry that is able to process this material, so it winds up in the trash regardless of whether it's a better option compared to traditional paper.

Food Waste:

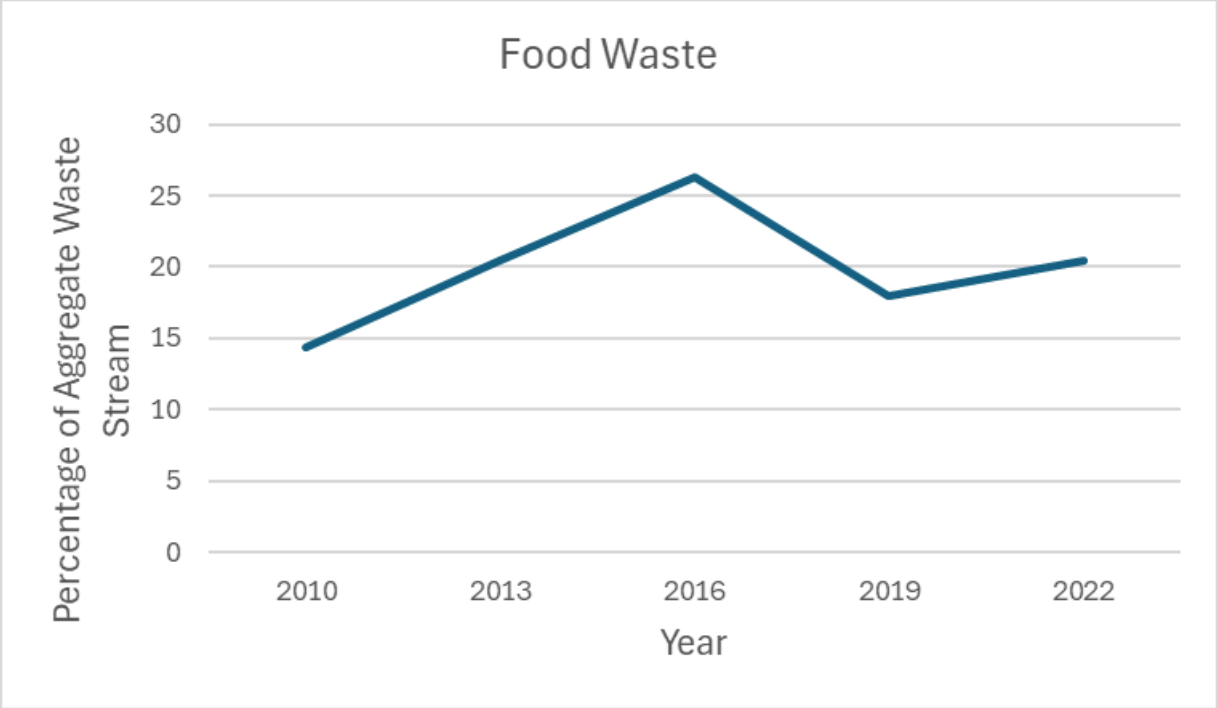

Figure 5: Pattern of food waste as percentage of total aggregate waste stream from 2019 to 2022.

Food waste demonstrates more stable values from 2010 to 2022. However, the increase from 2019 to 2022 could be related to the effects of the pandemic. While it is easy to think of food waste as a household and consumer issue, there are 8 previous stages in the food supply chain where food can be lost before it reaches consumers (Alexander et al 2013). While composting is an important practice to help mitigate food waste, it should not be the primary focus of policy efforts. Instead, policy makers should first focus on source reduction, then food rescue for people, food rescue for animals, and finally composting. This is a hierarchy that is not generally thought of, but crucial for crafting the most effective policies.

Aggregate Plastic:

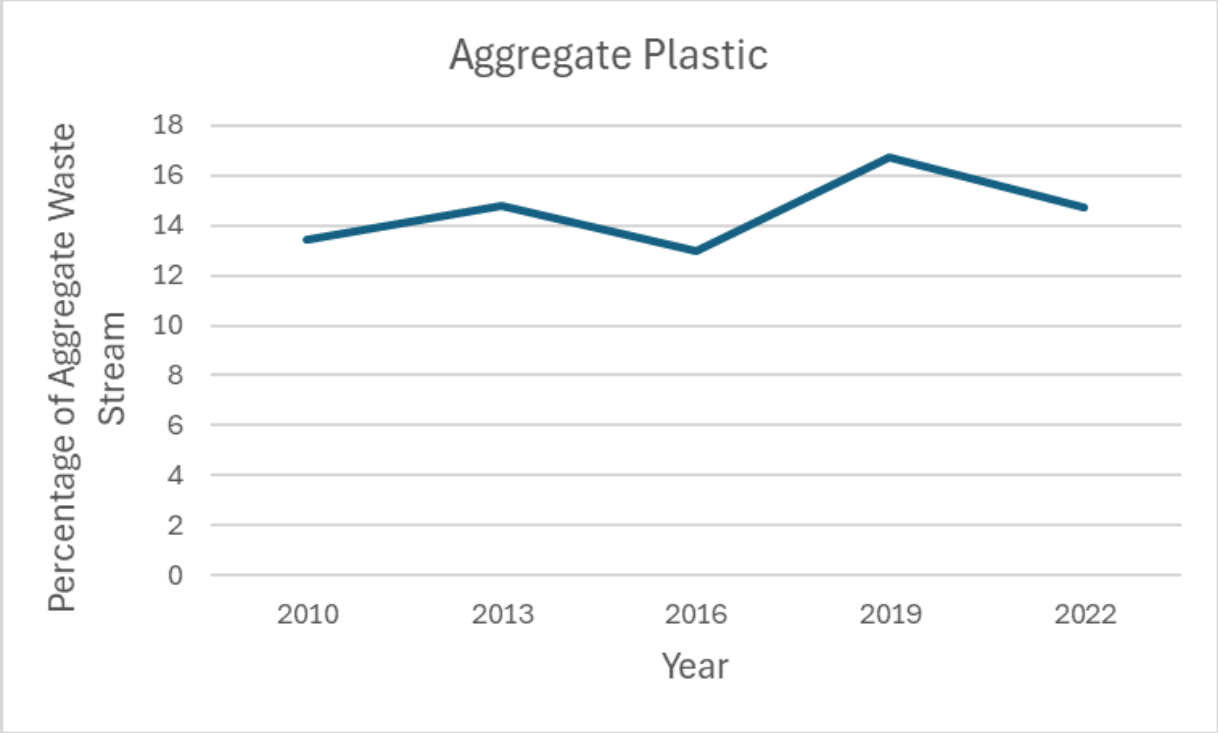

Figure 6: Pattern of total plastic waste as the percentage of the total waste stream from 2010 to 2022.

Like PET plastic and waxed board, the overall plastic waste stream is driven by the market for recyclable materials. Markets are often affected by policies and events. Similarly, the Chinese National Sword initiative, which banned the import of 24 recyclable commodities, affected the market for recycled plastic in 2017 (Los Angeles County). Up until 2018, China was taking 75-80% of the world's recycling, which had a trickle down effect on the MRFs. After the ban and once the burden was placed on these facilities, MRFs were less willing to accept materials that could be classified as nuisances because there was less of a market for them. Subsequently, more plastic goods entered the waste stream in 2019.

Based on the Covanta data and with input from Kari Parcell, we concluded that there were 4 main factors affecting the composition of the MSW of the SEMASS facility over the course of 14 years, which included MRFS, China's National Sword initiative, markets, and the changes brought about by the pandemic. The characterization of the waste stream is strongly influenced by market supply and demand. If there is high demand for a certain material stream, then people will be willing to pay more for it, and less of it will end up in the trash. Thus, it is crucial to factor in market cycles when developing methods of predicting municipal solid waste. However, unforeseen effects can greatly interrupt these market trends and cycles, as evidenced

by the changes in certain waste streams in years following important events such as the Chinese ban on recycled goods and the Covid-19 pandemic.

Section 2: Waste Forecasting Guideline

While it is important to contextualize current data in order to understand what factors may be driving changes in municipal solid waste, this information can also be used to inform our expectations of how municipal solid waste will change in the future. In addition to market influences and unpredictable shock events, there are certain societal, environmental, and economic factors that influence the composition of MSW. For example, environmental variables such as temperature can be used to predict MSW. In fact, temperature is considered the most relevant variable ahead of precipitation and humidity when it comes to MSW prediction because it affects consumer patterns (Izquierdo-Horna et al, 2022).

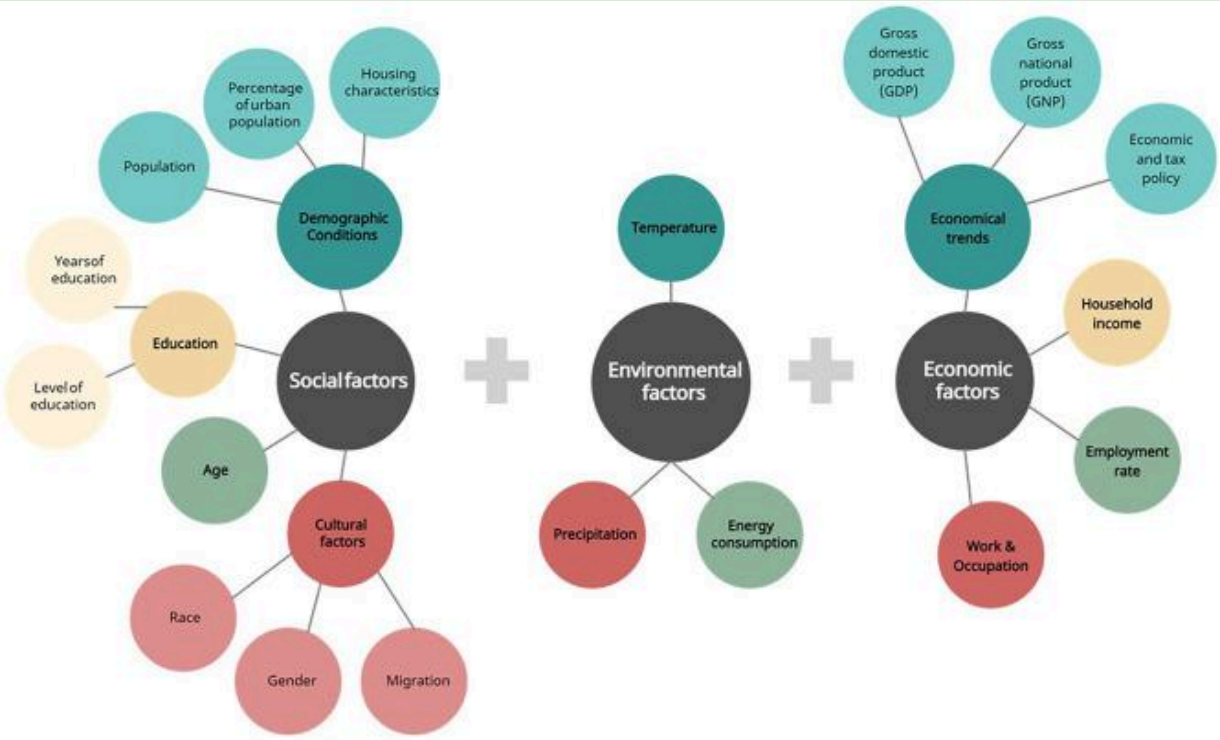

Figure 7: Independent variables associated with solid waste production

Sociocultural variables that influence solid waste generation include age, population growth and density, and education. In general, younger population groups have a different contribution to MSW generation when compared to older people. In addition, variables such as population growth, population density per square meter, and number of households per dwelling demonstrate a positive correlation with MSW generation (Izquierdo-Horna et al, 2022).

Education also has a significant impact on MSW generation. Educated people are more likely to be interested in market products, and potentially have a higher probability of affording them. Ultimately, higher education is found to have a positive impact on MSW generation rates (Keser et al 2012).

Finally, economic factors such as per capita income, per capita GDP, and economic and tax policies all have an impact on MSW output. As per capita income and per capita GDP increase, there is a historically positive correlation with municipal solid waste (Miller et al 2009). While high income households and cities may generate less food and green waste, they do end up generating more dry waste that could be recycled, such as plastic, paper, cardboard, metal and glass (The World Bank). Once an increase in income level occurs, the consumption pattern of a household is impacted, leading to changes in the composition and quantities of municipal solid waste (Nguyen et al, 2020).

The level of importance of these variables in predicting MSW generation was conducted through a series of regression analyses, which determined that these indicators were statistically significant in predicting MSW generation values. Because of this significance, these factors are incredibly important in understanding how MSW generation may change over time. If we can understand how these factors are expected to change in the future and their relationship with MSW, we can inform expectations of how municipal solid waste is expected to change in the upcoming years and use that information to generate policies.

Linear regression analyses are models that identify relationships between one dependent variable and one or more independent variables. The output of these analyses is a linear relation equation between the dependent and independent variables. Regressions are useful in determining correlations between variables, and for making predictions using that relation (Uyanik and Guler 2013). However, while useful for prediction and forecasting, it is important to note that causal relationships cannot be determined with simple multivariate and univariate models without additional analysis.

In the Town of Amherst, New York, multivariate regression techniques were put into practice in order to inform short and long-term planning of municipal solid waste management. In order to predict MSW tonnages over the course of the year in Amherst, an equation was developed that included the following variables:

PROPVALU	The average monthly value of single family residential housing (used as a proxy to capture consumption spending)
NOMCOSTO	The average monthly nominal collection and disposal cost of MSW in dollars per ton
POPDENS	A measure of population density calculated as persons per square mile
AVGTEMP	The average monthly temperature in degrees Fahrenheit
PRECIPIT	The monthly precipitation rate in inches
MSW_t	Monthly MSW tonnages over the course of a year

Table 1: Variables used in the Town of Amherst's forecasting equation, and their associated meanings.

Equation: MSW_t = (7,312.540) + 0.0027 PROPVALU + 27.384 PRECIPIT + 12.809 AVGTEMP + (7.745) NOMCOSTO + 4.364 POPDENS + (78.482) JANSF + (602.444) FEBSF + (249.104) MARSF + (223.971) APRSF + (114.335) MAYSF + (140.254) JUNSF + (315.942) JULSF + (265.103) AUGSF + (332.392) SEPSF + (311.719) OCTSF + 12.657 NOVSF

The dummy variables with the month abbreviation and the SF suffix were included to capture seasonal variation in MSW generation. The seasonal effect for December is captured by the constant term. This monthly time series model can be used for both monthly and annual projections of total MSW to evaluate the tonnages necessary for management and for infrastructure assessment purposes (Miller et al. 2009). By collecting similar data and conducting similar analysis as completed by the Town of Amherst, it would be possible for other towns, such as the Town of Dennis, to build their forecasting capacity. In forecasting municipal solid waste, it is important to remember that there is inherent uncertainty built into every model, and that limiting factors such as data availability can restrict the robustness of an analysis, both of which must not be ignored by end-users. However, while these forecasts may be uncertain, they are not without their uses in informing policy and regulatory decisions at local and national scales.

Section 3: Recommended Municipal Actions

Based on inferences extrapolated from the SEMASS report and information from local experts, there are certain policies that the Town of Dennis may be able to take in order to minimize their municipal solid waste. Besides implementing regulatory policies in order to

manage waste output, it is important for towns to take actions that encourage residents and businesses to reduce their waste instead of forcing them. Some of these potential actions include home composting programs, establishment of special collection sites, a town swap program, and more. By taking municipal action to mitigate waste in these specialized ways, Dennis can target specific problem waste streams in order to most effectively mitigate their waste.

As demonstrated by the SEMASS data, organic waste makes up the largest portion of total municipal solid waste, at 29.6% (SAK Environmental 2023). Thus, targeting organic waste would have a massive impact on total MSW (Vacquez and Soto 2017). Already, the Town of Dennis has realized the importance of targeting food waste, demonstrated in the "Challenge" for the Dennis community to start food composting at home or at the Dennis Transfer Station (The Town of Dennis). However, Dennis can further encourage home composting by helping residents get started with discounted compost bins, as well as promoting informational awareness on the dos and don'ts of home composting. Towns such as Arlington and Lexington, MA have found success when they implemented these programs (Arlington, Massachusetts and Lexington, Massachusetts).

It is important that food waste is targeted at the household level, but it is also important to hold businesses accountable for the role that they play in producing waste. According to the MassDEP, more than half of the waste produced in Massachusetts comes from the commercial sector. Thus, to encourage small and medium sized businesses to mitigate and/or divert waste, an information or "how to" campaign can help businesses get started on their own recycling and composting programs (Massachusetts Department of Environmental Protection). A major benefit of this action is that it shifts some of the burden of waste management off of governments and households and onto business, which are the primary institutions responsible for waste production. Finally, with consumers increasingly looking for sustainable and green options, starting these programs may even be good for business.

Beyond single use plastics, glass, and metals, there are many goods that can be difficult for residents to recycle, such as furniture, electronics, and other miscellaneous items. To help repurpose these items, the Town of Dennis used to host a swap program at the transfer stations to facilitate the recycling of these items. Unfortunately, this program was discontinued due to costs and other factors (Friss 2017). However, another way to engage communities and encourage them to recycle is through special events. Annual or semi-annual events are much more cost effective and may potentially excite residents more. These types of events can be turned into festivals or Earth Day celebrations to engage residents and help them appreciate the importance of recycling and waste management (Massachusetts Department of Environmental Protection). Towns that have seen success by hosting these events include Concord, Massachusetts, which has been hosting a swap and drop event for the past four years (The Town of Concord, Massachusetts).

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