THE CLASS OF 1964 POLICY RESEARCH SHOP

SUSTAINABLE WASTE MANAGEMENT

PRESENTED TO THE NEW HAMPSHIRE HOUSE COMMITTEE ON ENVIRONMENT AND AGRICULTURE

Representative Howard Pearl, Chair

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PREPARED BY:

FRANDY RODRIGUEZ
KELLY ZEILMAN
MADELINE GOCHEE
AMY PARK

NELSON A. ROCKEFELLER CENTER FOR PUBLIC POLICY AND THE SOCIAL SCIENCES
Contact:
Nelson A. Rockefeller Center, 6082 Rockefeller Hall, Dartmouth College, Hanover, NH 03755
http://rockefeller.dartmouth.edu/shop/ • Email: Ronald.G.Shaiko@Dartmouth.edu

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EXECUTIVE SUMMARY

Due to budget cuts in the Department of Environmental Services (DES) Solid Waste Management Bureau, New Hampshire has fallen behind in planning for the future of solid waste management. Four of the six landfills in the state are expected to close within the next decade, while the volume of trash diverted to landfills is not declining. This report explores the state of waste management in New Hampshire, investigates how other states are handling waste management challenges, and offers feasible solutions to reduce dependence on landfills in New Hampshire. The literature review explores the data available on waste management in New Hampshire, recycling, mass-burn waste-to-energy, and landfill gas-to-energy. Then, the body of the paper details landfill gas-to-energy, waste-to-energy, and reduction of solid waste as solutions to the landfill predicament in New Hampshire. The report closes by offering recommendations on steps that may be taken in New Hampshire, based on the findings of three previous sections, with the goal of managing waste in both an efficient and environmentally friendly manner.

1 INTRODUCTION

Solid waste management is an issue that affects all New Hampshire residents. The relentless stream of solid waste traveling to landfills is not a reliable waste management solution for the future. It is imperative that both the status of solid waste management in New Hampshire and potential alternatives to landfills are fully analyzed and considered for the future of the state. It is important of focus on landfill alternatives now to ensure that New Hampshire has an informed plan for solid waste management in the years ahead. Currently, House Bill 1422 has been introduced in the New Hampshire House of Representatives. It is an act to establish "a moratorium on the issuance of permits for new landfills or the expansion of existing landfills for the purpose of studying the creating of municipal waste districts."[1] In line with the bill, present consideration of alternatives to landfills will ensure that New Hampshire is prepared to present the strongest waste management solution for its residents. Future-focused planning today will help mitigate the foreseeable problems of the future.

The purpose of this paper is to study solid waste management in New Hampshire and to explore potential solutions to eliminate the need to increase landfill capacity. To satisfy this goal, we will explore the potential to reduce the volume of waste through recycling in order to minimize the amount of trash in landfills and the need to export garbage to other states. We will also investigate recommendations to aid the state in a transition away from landfills. These solutions may also reduce the net volume of trash by finding alternative disposal methods that are economically and environmentally sustainable. In order to identify possible legislation, we will analyze similar policies enacted in counties across the United States to understand the costs, benefits, and applicability of those strategies. The goal of this project is to provide a baseline analysis for the commission created by House Bill 1422 to initiate a comprehensive assessment of changes that may be made to waste management procedures in New Hampshire.

2 SOLID WASTE MANAGEMENT IN NEW HAMPSHIRE

Solid waste management (SWM) efforts in New Hampshire has fallen far behind those of neighboring states as well as nationally. This is primarily attributed to budget cuts to the Department of Environmental Services' (DES) Solid Waste Management Bureau.[2] Over a decade ago, DES had a Planning and Community Assistance Section overseeing SWM in each municipality. Today, all but one of the positions have been eliminated.[3] The lack of resources has left municipalities without standardized municipal solid waste (MSW) procedures, an inefficiency that has left the state in an unfavorable situation, especially as the amount of MSW produced far exceeds landfill capacity.

There are six operating landfills in New Hampshire, three public—which only accept MSW from New Hampshire and Vermont—and three private—which accept MSW from various areas (See Table 1). About 50 percent of the MSW accepted by NH landfills comes from out-of-state sources. This further constrains landfill capacity as four landfills are predicted to close before 2030.[4]

TABLE 1

Active New Hampshire Disposal Facilities (Source: Biennial Report)

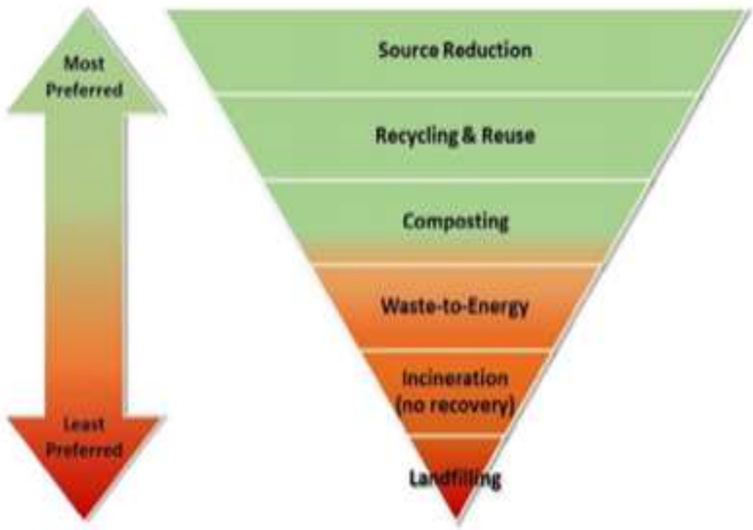
Facility Type	Facility Name	Location	Service Type / Service Area	Earliest Anticipated Closure Date
Waste-to-Energy Incinerator	Wheelabrator Concord Company L.P.	Concord, NH	Commercial / Unlimited	None
Incinerator (no resource recovery)	Hebron-Bridgewater Refuse District	Bridgewater, NH	Limited Public / Limited	None
Landfill	North Country Environmental Services, Inc.	Bethlehem, NH	Commercial / Unlimited	April 16, 2021[4]
	Four Hills Secure Landfill Expansion	Nashua, NH	Limited Public / Limited	April 15, 2023[5]
	Mount Carberry Secure Landfill	Success, NH	Commercial / Unlimited	April 29, 2025[6]
	Lebanon Regional Solid Waste Facility	Lebanon, NH	Limited Public / Limited	est. 2027[7]
	Lower Mount Washington Valley Secure Solid Waste Landfill	Conway, NH	Limited Public / Limited	est. 2033[8]
	TLR-III Refuse Disposal Facility	Rochester, NH	Commercial / Unlimited	June 30, 2034[9]

2.1 LANDFILL REGULATIONS

RSA 149-M is the main statutory law that governs solid waste management in New Hampshire. It includes requirements and regulations relating to building and maintaining solid waste landfills to safeguard the environment. It also outlines a preferred hierarchy of solid waste management practices, established in 1990 (See Figure 1). Per RSA 149-M, DES is also required to publish a solid waste management plan every six years. The last plan was published in 2003, highlighting the shortfalls of the Department.[5]

FIGURE 1

Hierarchy of Waste Management in New Hampshire (Report of the Committee to Study Recycling Streams and Solid Waste Management in New Hampshire 2019)



2.2 SOLID WASTE MANAGEMENT BUREAU

Unlike the air and water divisions of DES, the Solid Waste Management Bureau has fallen far behind on funding in the past decade. This is primarily attributed to the way the Bureau is funded, which is through general funds that are supported by taxes and fees from all across the state. The other divisions of DES are instead funded by fees—that is, pay to pollute. Hence, the Bureau is presently underfunded and as a result understaffed. Being underfunded leads the Bureau make decisions based on what it is required to do by regulation, meaning it adheres more to the regulatory process and rather than focusing on planning. According to a research interview with Lebanon's Solid Waste Superintendent Marc Morgan, lack of planning has disconnected municipalities across the state since none of them really knows what other landfills in neighboring towns are doing. Instead, they each do their own thing, which has led to complications in planning, particularly with regard to waste coming from out of state.

Ineffective waste management planning may lead to detrimental long-term consequences for NH. The state may consider conducting further research to assist in updating the now outdated waste management plan. In such an investigation, the state may consider what neighboring states are doing that may affect NH and explore new funding methods, such as a fee system, that may increase financing for the Bureau. It is worthy to note here that House Bill 1702 was recently introduced with the goal of establishing a solid waste working group that would revise the 2003 waste management plan, though it did not pass.[6]

3 ALTERNATIVES TO LANDFILLS

Alternative disposal methods to landfills are growing in prominence. In order to investigate the feasibility of altering solid waste management policies in New Hampshire, it is imperative to conduct a review of current policies and potential alternatives. In this section, we will explore the status of waste management in New Hampshire and examine landfill gas-to-energy (LFGTE) and mass-incineration waste-to-energy (WTE). Europe and East Asia have invested heavily in solar parks[7] and WTE facilities.[8] Federica Cuchiella focuses on WTE plants in a literature review of Sustainable Waste Management practices, noting that "technologies including the landfill gas recovery system, incineration, anaerobic digestion (A.D.) and gasification" are encompassed in the broad term of "waste-to-energy" processes.[9] A complete list of WTE technologies and their economic implications is presented in Appendix A. Disposing of waste through mass-incineration and collecting energy from landfill gas are both viable potential solutions to minimize the environmental hazard of continued landfill usage.

3.1 LANDFILL GAS TO ENERGY (LFGTE)

While not an alternative to landfills, LFGTE facilities can make existing landfills more environmentally sustainable by repurposing the gas released by landfills and WTE plants. Landfill gas (LFG) is composed of approximately 50 percent methane (CH_4) and 50 percent of carbon dioxide (CO_2).[10] Though both gases negatively affect the environment, CH_4 is over 21 times more potent than CO_2. LFGTE facilities capture LFG through a series of wells that draw out the methane through a vacuum process.[11] The gas is then compressed and chilled in an effort to draw out any liquids through condensation. Afterwards, LFG is flared and converted into energy through one of three methods:

1) Electricity Generation: Around 72 percent of LFGTE facilities use this method. An assortment of technologies are used to generate electricity, such as reciprocating internal combustion engines, gas turbines, micro-turbines, and fuel cells. Generally, the reciprocating engine is the preferred conversion technology because it is inexpensive and efficient. Gas turbines are typically utilized in large LFGTE facilities; whereas micro-turbines are utilized in smaller ones. This method also produces thermal energy, which can be captured through cogeneration projects in the LFGTE facilities to be sold for revenue production. There is currently one such facility in Hillsborough, NH.
2) Direct Use of Medium - Btu Gas: Around 18 percent of LFGTE facilities use this method. These landfills pipe LFG directly to nearby customers to replace another fuel, such as natural gas or coal. This method does not require as much technological equipment compared to the other two methods, requiring only slight changes to present combustion equipment. Additionally, this method may be utilized to evaporate leachate. There is currently one such facility in Coos, NH.
3) Renewable Natural Gas: Around 10 percent of LFGTE facilities use this method. These landfills remove moisture, CO_2, and other contaminants from LFG while also lowering the amount of oxygen and nitrogen in the gas. Consequently, CH_4 levels in the gas will increase to a rate of about 90 percent or higher, which is then inserted into natural gas transmission or distribution pipelines to be sent to customers or used in the facility itself. This gas is used as a substitute for natural gas, which generates electricity, heat, and vehicle fuel. It can also be used as a bio-product feedstock. There is currently one such facility in Rochester, NH.[12]

Typically, the collector and flare system expenses in a 40-acre LFGTE facility are around $1,143,000 ($28,600 per acre) in capital costs and $191,000 ($4,800 per acre) in operations and maintenance costs.[13] Federal and state programs, such as the Landfill Methane Outreach Program, found in the Database of State Incentives for Renewable Energy (DSIRE), can subsidize these costs.[14] Facilities may also be privatized through a merger between a landfill and a private entity to cover the majority of costs.

LFGTE facilities provide a number of economic and environmental benefits. These facilities create new revenue streams from the generation and distribution of gas and jobs related to a facility's design, construction, and operation.[15] Likewise, these installations reduce GHG emissions that improve air quality, reduce odors associated with landfills, and establish health and safety benefits to surrounding areas.[16] These facilities may also be operated continuously, unlike other renewable energy technologies, similar to fossil fuel-fired plants. This makes it easier to integrate these facilities into the local power grid.[17] Equally important, these facilities have proven technology that have been used for decades, meaning there is less concern on behalf of facility owners, operators, and potential investors.[18]

3.1.1 LFGTE IN NEW HAMPSHIRE

Though many landfills in New Hampshire have the appropriate equipment required for the creation of electricity from landfill gas, many do not participate in the endeavor. Currently, there is one LFGTE facility in Rochester, NH at the Turnkey Recycling and Environmental Enterprise (TREE) facility, which demonstrates how possible LFGTE facilities in the state may function. TREE comprises four operational units owned by Waste Management, Inc. (WM); each unit relies on electricity generation to produce power ranging from 0.94 MW to 4.40 MW a year.[19] After WM realized it was producing far more methane than it could productively utilize in engines to make electricity, WM partnered with the University of New Hampshire (UNH), to whom it provides 80 to 85 percent of renewable energy delivered through 12.7 miles of underground pipelines.[20] The partnership developed after WM realized it was producing far more methane than they could productively utilize in engines to make electricity. UNH, on the other hand, wanted to address its fluctuating energy costs (i.e., price of electricity, oil, natural gas) and concluded that renewable energy would have a much more stable price and as such would make more economic sense. According to a research interview with UNH's Utility Systems Manager, Dave Bowley, and UNH's Campus Energy Manager, Adam Kohler, partnering with WM seemed like the best viable option for both parties.

Fortunately, the building process was fairly feasible and straightforward for both parties. Construction for a landfill gas processing plant that "scrubbed" the gas began at TREE in 2007, consisting of 300 extraction wells. UNH already had an existing cogeneration plant on their campus to utilize the methane provided by TREE as fuel to produce heat and electricity for their five million square-foot campus.[21] Additionally, the right of way granted by the Department of Transportation allowed for the pipeline to parallel the highway and the Pan Am railroad and thus eliminated any negotiations with individual property owners. The significant hurdle for the project was its cost, initially estimated to be $45 million, but eventually reached $49 million. However, the project proved to be fruitful for UNH as it paid itself back in ten years and is now limited to operational costs, which range from $2 million to $3 million a year. At the start of the project, TREE collected 13,000 standard cubic feet of gas per minute, but today it is down to 8,000 standard cubic feet of gas per minute because of a recent rise in recycling and composting efforts. However, according to Bowley and Kohler, this decrease in gas expected did not affect the payback timeline. Different methods used by UNH to payback for the project included selling excess gas to the power grid and getting renewable energy credits (REC) offered by NH. It is important to note that UNH has received more capital through RECs than by selling electricity to the power grid since wholesale electricity costs have plummeted since the project began in 2007.

The benefits of the project have outweighed its costs, which were paid back within ten years. With the more stable price of renewable energy, UNH has experienced considerable cost savings and improved budget control. Greenhouse gas emissions for TREE have also significantly decreased and are now 57 percent below 1990 levels.[22]

3.1.2 LFGTE IN RHODE ISLAND

We believe Central Landfill in Johnston, Rhode Island demonstrates how a new, larger LFGTE facility in New Hampshire could function. If New Hampshire were to decide to operate a large LFGTE facility, we believe that adopting a model similar to that of Central Landfill may be most fruitful. As the second largest LFGTE facility in the U.S., Central Landfill consists of two operational units (a closed and open landfill), owned and operated by the Rhode Island Resource Recovery Corporation (RIRRC). Broadrock Renewables, LLC also owns and operates a separate facility on the site where captured landfill gas is converted into energy. The two facilities combined generate 33.4 MW, which is then delivered to the local transmission grid at a rate of 45.6 percent electrical efficiency.[23] We considered four topic variables when identifying this LFGTE facility that encompass a wide range of factors necessary to keep in mind when determining the feasibility of building new LFGTE facilities in New Hampshire. The topic variables were building process, cost, operation, and political implications.

The Central Landfill LFGTE facility includes a collection system comprised of 6,000 collectors (i.e., vertical wells and horizontal gas collectors), a clean-up and compression system to “scrub” the collected gas, a pipeline that transports the gas within their facility, a combined cycle generating facility, and a substation that delivers gas to the local power grid.[24] According to a research interview with RIRRC Education and Outreach Manager, Madison Burke, and Director of Engineering, Inga Lermontov-Hoit, this facility is able to collect 11,000 standard cubic feet of gas per minute, with which they are able to produce $40 million of energy a year. The overall costs associated with building such a facility was $115 million and it is estimated that between $22 million and $23 million is spent annually on maintenance. Usually, third parties approach RIRRC and take care of gas collection to sell it afterwards.

The benefits of such a project have been immense for Rhode Island. The plant successfully reduces carbon emissions by 1.27 million tons per year.[25] It also indirectly reduces carbon emissions by 158,000 tons a year and saves 2.1 trillion Btu annually.[26]

3.1.3 LFGTE CANDIDATES IN NEW HAMPSHIRE

Currently, Lebanon, NH and Bethlehem, NH are looking to implement LFGTE facilities in their landfills. For the City of Lebanon, a LFGTE facility would assist in accomplishing its goal of reducing greenhouse gas emissions by 80 percent by 2050.[27] As of right now, the Lebanon Regional Solid Waste Facility landfill has 12 interior landfill gas extraction wells situated in the 25-acre double lined active Phase I/II landfill that were installed in 2014.[28] The captured gas is then conveyed through pipes to a blower and flare system that was installed in 2015.[29] Estimates indicate that future landfill gas production in the facility is expected to remain between 380 and 400 standard cubic feet of gas per minute through 2028, a year after the landfill is expected to reach capacity.[30] The efficacy of recuperating landfill gas created at the Lebanon Landfill site will rely on a few variables including: the breadth of the landfill gas collection system, the effectiveness of the gas recovery equipment, the operating conditions of the gas collection and recovery facilities and whether the landfill is capped or uncapped.[31] The LFGTE technology options for a small-to-medium sized landfill, such as the Lebanon Landfill, are reciprocating engine-generators, micro-turbines, and fuel cells.[32] In this instance, the best possible option for the Lebanon Landfill would be to utilize micro-turbines. They would allow for the facility to scale up their LFGTE operations in smaller increments as landfill gas increases, have fewer moving parts and thus have lower operating and management costs, combust gas with lower methane content and lower their overall greenhouse gas emissions. This way, rather than having a singular reciprocating unit of 800 kW or 1,000 kW, the facility can have four or five 200 kW portable micro-turbines.[33] Though the expected costs are not clear, the City has set aside around $3 million for the endeavor.[34] Programs like LMOP and partnerships with private entities may subsidize these costs. The New Hampshire legislature also has the option of reinstating tax incentives for these projects to provide investors with tax breaks.

As for the Town of Bethlehem, Liberty Utilities and RUDARPA Inc. have partnered to develop a LFGTE facility at the North Country Environmental Services (NCES) solid waste landfill.[35] For Bethlehem, a facility of this kind would lessen the greenhouse gas emissions at the landfill, lower fuel costs, and stimulate the local economy. The project was approved in 2018 and has yet to be installed, due to delays related, in part, to the COVID-19 pandemic. It aims to capture landfill gas that would then be used to provide natural gas to an estimated 6,000 homes in New Hampshire.[36] While there is already a flare system in place, there still remains the necessity of installing a pipeline that runs to the RUDARPA facility, where the gas would be purified and compressed.[37] The cost of such an endeavor ranges from $12 and $15 million.[38] If the landfill does close in 2026, as is presently expected, developers forecast that it can still produce enough landfill gas to keep the facility operating for 15 more years subsequently.[39]

3.1.4 CONSIDERATIONS FOR NEW HAMPSHIRE

The State of New Hampshire needs to consider an assortment of factors when undertaking future LFGTE projects. First, it is important for facility owners, operators, and potential investors to examine which proven technology will be of best fit for their facility. This will be dependent on the size of the landfill as well as how much standard cubic feet of gas per minute it produces. Furthermore, it is crucial that administrators weigh the expected benefits of such a project against its cost and determine whether the long-term benefits exceed the initial costs. Administrators also need to assess the most cost-effective method they can pursue, whether that is by merging with private entities or receiving funding. Additionally, stakeholders need to evaluate the impact that building an additional LFGTE facility in the state would have on air quality and the local power grid. In short, constructing additional LFGTE facilities may be a viable option for NH municipalities to undertake in order to stimulate their economies through the creation of jobs, mitigate climate change, and lower fuel costs.

3.2 MASS-BURN WASTE-TO-ENERGY (WTE)

Mass-burn incineration is the most commonly used WTE technology.[40] First, trash is sorted to remove hazardous or recyclable materials before incineration. Then, there is a large-scale combustion, the heat of which is used to convert water into steam, turning a turbine generator to produce energy. The ash produced is filtered and then landfilled. This alternative does not entirely eliminate the need for landfills; however, states have successfully reduced the volume of their landfills by 90 percent by transitioning to an incineration plant.[41] Chuchiella concludes that mass-burn incineration is the "best solution" to landfills from both an environmental and financial standpoint, as does Sieting Tan et al. and the Rhode Island Resource Recovery Corporation, which prepared a white paper on the possibilities of waste processing technologies to deal with MSW.[42] While other technologies exist, no large-scale solution has become as widespread as mass-burn incineration technology.[43]

Waste-to-Energy as a process to dispose of waste has been federally categorized as a renewable resource by laws such as the EPA Clean Power Plan.[44] Thirty-one states have included WTE in their renewable state statutes, though New Hampshire has yet to do so.[45] WTE plants reduce greenhouse gas emissions (GHGs) in the following ways:

1) Generate energy that otherwise would be created by fossil-fueled facilities.
2) Divert solid waste from landfills where it would have emitted methane for generations.
3) Recover metal for recycling, saving GHGs and energy associated with the production of goods from virgin inputs.

The EPA estimates that WTE reduces GHG emissions by one ton of CO_2 equivalents for every ton of waste diverted from a landfill. Further, WTE has clear economic benefits. It is projected that every $1 of revenue generated by the WTE sector injects $1.77 into the economy through intermediate purchases of goods and services and payments to employees. Another notable benefit of WTE is its relationship with community recycling. Concerns that WTE facilities may create a moral hazard because the trash can be incinerated at low costs have been debunked. An assessment, conducted by Elieen Brettler Berenyi, indicates the recycling rate of communities served by WTE facilities was slightly *higher* than the state average in 16 out of 21 states utilizing WTE. This disproves the causal link between WTE and lower rates of recycling.[46]

There are currently 75 operating WTE plants in the United States, 58 of which are mass-burn incineration, 13 are Refuse Derived Fuel (RDF), and four are modular incineration plants.[47] As of 2015, no WTE plants had been built in two decades (Palm Beach, Florida recently opened a plant).[48] The majority of WTE plants are located in the northeast, where population densities are higher, making the transportation process more cost-effective.[49] Case studies of plants in Westchester County, NY, Pinellas County, FL, Marion County, OR, and York County, PA illustrate WTE plants can succeed in a variety of local environments at diversified capacities.[50,51] New Hampshire also operates one Waste-to-Energy plant in Merrimack County.[52] Opened in 1989, Wheelabrator Concord processes approximately 191,600 tons per year, producing 14MW of energy to power 14,460 homes in the area. A second[53] New Hampshire WTE facility closed its doors in 2013 due to air emission concerns from residents.[54]

As mentioned, the most common criticism of WTE technology is air pollution generation. Burning MSW produces nitrogen oxides, sulfur dioxide, and trace amounts of toxic pollutants, such as mercury compounds and dioxins.[55] To deal with this problem, more than $1 billion dollars has been invested in upgrades to air quality control systems as per the Clean Air Act. Table 2 below illustrates the dramatic reductions in WTE plant pollutants after implementation of EPA regulations. Mass-burn incineration plants are now equipped with combustion control systems to filter the ash out of the smoke that exits the factory.[56] In addition, facilities employ sophisticated air quality control equipment, such as selective non-catalytic reduction or "SNCR" scrubbers, activated carbon injection, and fabric filter baghouses. It is also important to contextualize the net effect WTE has on air quality. According to the EPA, WTE facilities produce electricity with "less environmental impact than almost any other source of electricity."[57] As Floridian WTE plant manager Wrobel notes, "garbage in a landfill [generates] methane [...] a greenhouse gas 28 times more destructive than any gas we emit from our facility."[58] Landfills are the third-largest human-generated source of methane in the U.S. Thus, long-term strategies to reduce the reliance on landfills will be net-positive for the surrounding environment.

TABLE 2

WTE Plant Pollution Reduction (Valdez 2009)

Pollutant	Total			Percent Reduction
	1990	2005	Reductions	
Dioxins, total mass, kg/yr	226	0.706	226.0	99.7%
Dioxins TEQ, kg/yr	4.42	0.0138	4.4	99.7%
Hg, tons/yr	56.7	3.72	53.0	93.4%
PM, tons/yr	18,630	1,066	17,564.0	94.3%
SO_2, tons/yr	38,270	6,118	32,152.0	84.0%
NO_x, tons/yr	64,900	49,500	15,400.0	23.7%
Cd, tons/yr	9.61	0.550	9.1	94.3%
Pb, tons/yr	172	8.70	163.0	94.9%
HCl, tons/yr	57,400	2,538	54,862.0	95.6%

3.2.1 WTE IN NEW HAMPSHIRE

To determine whether a WTE plant would succeed in New Hampshire, there is no more relevant case than the plant that already exists at the Wheelabrator Concord facility in Concord, New Hampshire. The plant opened in 1989 and has two boilers that generate electricity from the steam produced by burning waste. It generates 14 MW of electricity from the 575 tons of post-recycled waste it incinerates per day.[59] Annually, it incinerates a total of 191,600 tons of post-recycled waste. This energy provides electricity to the facility itself as well as 14,460 homes in the state.[60] The environmental benefits have been substantial as it annually saves 195,641 barrels of oil.[61]

3.2.2 WTE IN FLORIDA

Another WTE plant whose model the state should likely consider if it were to attempt operating a larger plant is the SWA Renewable Energy Facility 2 (REF2) in Palm Beach County, Florida. This plant began operations in 2015, which makes it the newest WTE plant in the United States by almost two decades.[62] According to a research interview with Ray Schauer, SWA Engineering and Public Works Director, the plant picks up garbage from the curbside, burns it in their furnace to generate steam that produces 96 MW of electricity, enough to power 40,000 homes. Most notable of this plant is their air cool condenser fans which cool down steam, turning it into water and losing less water to the atmosphere overall. The costs associated with the project were $672 million of which 68 percent was funded from the tax base for an estimated annual $175 assessment per household. Annually, the plant spends $300 million on its operations.[63]

3.2.3 CONSIDERATIONS FOR NEW HAMPSHIRE

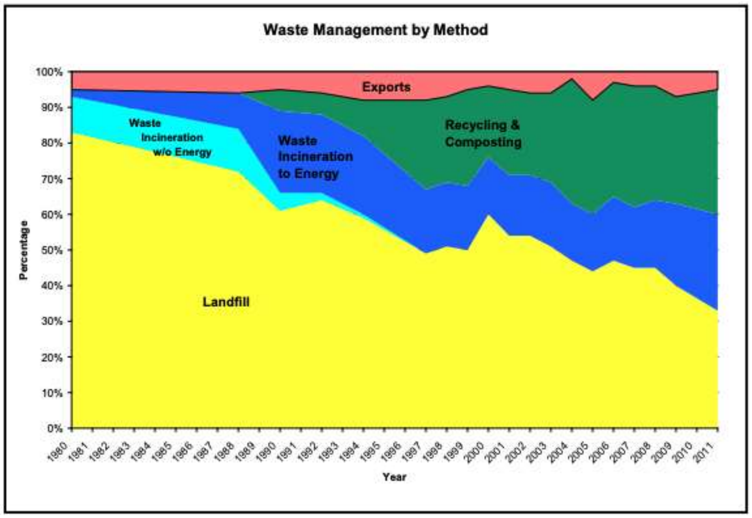
Despite there already being a WTE plant in New Hampshire, we do not think building additional plants of this kind is the most viable option for the state. There are many systemic changes that need to occur before the state considers this possibility. For example, the state would have to consider investigating and possibly altering its current hierarchy of sustainable waste management options. Incineration currently is the second least preferred method of reducing waste in the state. As such, any projects of this nature would have to overcome significant systemic barriers and stigmas associated with it. Furthermore, we believe the state would be proceeding too quickly into such an advanced endeavor without having ameliorated the outstanding issues present in the current waste management system. Essentially, further construction of WTE plants may be something the state undertakes after it manages other pressing problems.

4 REDUCING SOLID WASTE IN NEW HAMPSHIRE

Beyond finding alternatives to landfills, New Hampshire can also reduce the amount of waste it is sending to current landfills. Recycling is an effective solution to reduce the volume of waste traveling to landfills. Although it is not mandated, recycling is one of the most preferred strategies according to the Waste Management Hierarchy.[64] Thirty-five percent of NH waste is recycled or composted (See Figure 2), but up to 80 percent of waste generated is recyclable.[65] Though the discrepancy between the rate recycled versus the rate than can be recycled is concerning, a positive takeaway is that there is untapped potential to reduce the volume of waste traveling to landfills. Economically, recycling is a cost avoidance strategy that will maintain low landfill tipping fees in the future through conserving space today.[66] Diverting waste from landfills is a somewhat difficult task currently because markets for recycled materials are particularly profitable at the moment. However, there are several laws that have been implemented in states similar to New Hampshire that can provide a framework for potential New Hampshire regulations.

FIGURE 2

Waste Management by Method (Source: Biennial Report)



4.1 VERMONT'S UNIVERSAL RECYCLING LAW

In 2012, the Vermont Legislature unanimously passed Act 148, the Universal Recycling Law, which in many ways is the gold standard for a waste reducing policy.[67] Vermont is a neighboring New England state and is similar demographically and economically to New Hampshire in many ways, so their legislation and its effectiveness can serve as a useful tool in determining how New Hampshire could reduce the amount of waste entering landfills in the state. The law bans three kinds of waste from trash bins: "blue bin" recyclables, which includes containers, cardboard, and paper; leaves, yard debris, and clean wood; and food scraps.[68] The law also requires trash pick-up companies to have parallel collection.[69] They must offer trash and recycling pick-up as one service for one combined fee, not allowing people to opt out of recycling and not forcing customers to pay an additional fee to have recycling pick-up.[70]

The law also requires that trash pick-up companies offer food scrap pick-up for any nonresidential customers and any apartment buildings with four or more units.[71] Additionally, any trash collection sites, such as transfer stations, also must accept food waste and recycling as part of the parallel collection element. Another aspect of the law is unit-based pricing or "pay-as-you-throw."[72] Waste collectors are required to charge for trash based on its volume or weight to financially incentivize waste reduction. Furthermore, the law establishes mandatory public space recycling, so any trash cans in public spaces must be accompanied by a recycling bin except for bathrooms.[73] Finally, the Vermont Universal Recycling Law includes a phased-in food scrap ban. Businesses and institutions that produce significant amounts of food waste are required to keep their food scraps out of the trash before residents are required to give the markets time to respond and create the necessary infrastructure.[74]

As expected, Vermont's Universal Recycling Law did come with associated costs. When fully implemented, the program was projected to cost households $7-9 more per month in fees for services.[75] Haulers would also need to invest in new and more equipment for expanded collection.[76] Total capital investments for the project were estimated to be $42-45 million over the nine-year implementation period, or an average about $5 million per year.[77] This cost is significant and must be accounted for in the development of waste reduction policies.

Vermont has had to make some changes to their Universal Recycling Law. In some cases, the Legislature realized the goals they set were not feasible. They pushed back the date when haulers were required to collect food scraps to allow the infrastructure to develop to handle that process and allowed transfer stations to charge separately for recycling, recognizing that set up was more practical.[78] Vermont also responded to global policy changes that affected their program. China's 2018 National Sword Policy, which banned the import of plastics and other recyclables has undoubtedly affected markets in the United States.[79] For example, mixed paper imports declined by a third in the year after China implemented their National Sword Policy.[80] Vermont recognized this situation and in the spring of 2018 the Legislature allowed for waivers to be requested to dispose of paper if the recycling market was insufficient.[81] However, as of January 2019, no waivers had been requested, indicating that the United States recycling market is responding to China's National Sword Policy and that recycling paper is not an insurmountable task for a New England State. These adaptations show that making change is worthwhile, even if initial policies are imperfect. The aim of the Vermont Recycling Law is to manage waste in a more efficient and environmentally sound manner without damaging the economy.

To date, the Vermont Universal Recycling Law has been successful in reducing that amount of waste that ends up in landfills. Despite the challenge presented by China's National Sword Policy and the fact that packaging is getting lighter, Vermont still recycled more in 2017 than prior to the enactment of the law.[82] Also, in 2017 more food scraps were collected than ever before, a nine percent increase from 2016.[83] Phase two of the food scrap ban began in 2015, which prohibited medium-sized institutions from throwing away their food scraps, and by 2015 food recovery was up 30 percent in the Vermont Foodbank and pickups of food from retailers were up 200 percent.[84]

In 2014, Massachusetts imposed a food waste ban, similar to the initial phases of food waste regulation in the Vermont Universal Recycling Law.[85] It has also had similar effects to the Vermont law, prioritizing food donation and causing businesses to develop their own methods for sustainably handling food waste, proving that Vermont is not an anomaly in their ability to keep food waste out of landfills.[86]

4.2 GLASS RECYCLING AND BOTTLE BILLS

Beyond what is outlined in the Vermont Universal Recycling Law, there are also steps New Hampshire may take specifically to reduce the amount of glass being sent to the landfills across the state. According to research interview conducted with Reagan Bissonnette, Executive Director of the Northeast Resource Recovery Association, or the NRAA, ideally, recycled glass would be sold back to companies to be melted down and made into new glass. However, 57 percent of New Hampshire residents recycle through the single stream recycling programs, which often result in glass that is contaminated.[87] The recycled glass is melted down to make new glass, but contamination has different boiling points than glass and can explode or get stuck in and break machines, so manufacturers are not interested in buying glass collected through single stream recycling.[88]

In order to collect less contaminated glass that may be sold to manufacturers, 10 states including Maine, Vermont, Massachusetts, and Connecticut, have enacted bottle bills.[89] Bottle bills establish collection centers for glass containers and give consumers a refund of between two and fifteen cents per bottle, and they have proved effective in reducing solid waste in the other New England states.[90] Residents do take advantage of the refunds. In the period of a year spanning from October 2019 through the end of September 2020, the redemption rate of non-liquor containers was 77 percent in Vermont; the redemption rate of liquor containers was 88 percent.[91] The laws are also effective in reducing waste. The Connecticut bottle bill went into effect in 1980; the Connecticut DEP had credited the legislation with reducing the solid waste across the state by five to six percent in the following year based on rough estimates of tonnage.[92]

In the absence of a bottle bill, the NRRA has developed a way to use glass collected through single stream recycling. Reagan explained that they crush the contaminated glass and turn it into fiberglass insulation, sand, gravel, and pavement for roads.[93] For the roads, the NRAA is currently only crushing glass small enough to meet the standards of the Department of Environmental Services, who regulates local roads. State roads, on the other hand, are regulated by the New Hampshire Department of Transportation and require glass to be crushed to a smaller size and mixed with another substance, such as asphalt.[94] However, these regulations have not been updated in many years; it may prove advantageous for the state to study the subject and determine if the regulations may be changed to a standard that is more compatible with NRAA efforts.

4.3 OUT-OF-STATE WASTE

If the focus is solely on reducing the waste that enters New Hampshire landfills, it cannot be ignored that a significant portion of that waste is trucked into New Hampshire from surrounding states. In 2017, Massachusetts sent nearly 400,000 tons of waste to New Hampshire and in 2018, 49 percent of municipal solid waste came from out of state.[95] It would be unconstitutional to ban out-of-state waste altogether under the commerce clause of the U.S. Constitution,[96] but if New Hampshire wants to reduce that amount of solid waste entering New Hampshire landfills, the state could make it more expensive to send waste to New Hampshire. Other states have implemented this kind of policy, such as Ohio, which charges $1-2 for every ton of waste generated outside of Ohio.[97] On January 14, 2020, SB 629 was introduced to the New Hampshire State Senate, which would have established a $1.50 surcharge per ton of waste sent into New Hampshire and established a fund with that money to be used for sustainable waste management in New Hampshire.[98] However, the bill died in committee and was not enacted.

5 RECOMMENDATIONS

Based on the research we conducted, we formulated these recommendations we believe the State of New Hampshire may consider regarding their future actions concerning solid waste management.

- New Hampshire could update their solid waste management plan that has not been revised since 2003. Such a task could involve forming a committee that further investigates the conditions of landfills in the state to offer accurate recommendations that pertain to modern times. As such, municipalities will receive guidance that corresponds to present-day developments.

- New Hampshire could provide more funding to the Solid Waste Management Bureau of the Department of Environmental Services. Past budget cuts to the Bureau have virtually left it unable to do its job in managing the waste in the state properly. Adequate funding will allow the Bureau to reach appropriate staffing levels to administer its programs. Moreover, it would also permit the Bureau to move away from its mainly regulatory process wherein it acts in response to occurrences rather than preparing for the future.

- New Hampshire could construct additional LFGTE facilities in their landfills as they may stimulate their economies through the creation of jobs while also ameliorating climate change and lowering the cost of fuel.

- New Hampshire could investigate and update the state solid waste hierarchy. The current solid waste hierarchy structure stigmatizes technology, like WTE, that can be remarkably beneficial to the state if done properly. Essentially, further construction of WTE plants can be something the state undertakes after it manages other pressing problems.

- New Hampshire could revisit, update, and pass new legislation regarding recycling and waste reductions efforts. Bills adopting aspects of the Vermont Universal Recycling Law into New Hampshire or a bottle bill could increase recycling efforts, divert more recyclable materials from landfills, and prove profitable for the state.

- Current DOT regulations for recycled glass could be studied to determine if the current rules could be adjusted to a standard the NRRA could feasibly meet. The DOT may seek to incorporate as much glass aggregate into newly paved roads as possible.

New Hampshire could impose a surcharge on out-of-state waste deposited in landfills. The revenue generated could be used for future sustainability and waste management projects.

- The state should continue to partner with other organizations in their work to develop sustainable waste management strategies. Municipalities should continue to work with the regional planning commissions and collaborate with nonprofit organizations like the NRRA.

6 CONCLUSION

The constraints that the municipal solid waste management programs of New Hampshire are experiencing may be attributed to both the dwindling capacity of landfills and the budget cuts the Department of Environmental Services Solid Waste Management Bureau has endured over the years. Therefore, considering alternatives to existing landfills, such as landfill gas-to-energy and waste-to-energy facilities, is an important component of the future of solid waste management in New Hampshire. Landfill alternatives may extend the capacity of existing landfills while also generating additional revenue streams. Reducing the waste that is currently filling the limited space in New Hampshire landfills is also a way through which the state can increase the longevity of their landfills. Reducing waste and expanding recycling programs, as well as more strictly regulating out-of-state waste, have the potential to lessen environmental impact while also generating revenue for the state. Analyzing the selected case studies for landfill alternatives and other state models for diverting waste from landfills is beneficial as these examples may serve as steppingstones for shaping a forward-looking solid waste management plan for New Hampshire.

7 APPENDIX

A: Summary of Municipal Waste Processing Technologies

Source: Rhode Island Resource Recovery Corporation

Available to the Rhode Island Resource Recovery Corporation

	Technology					Economic Issues			
Alternative	**Description**	**Experience Record**	**Size Applicability**	**Reliability**	**Environmental Issues**	**Capital**	**Operations/ Maintenance**	**Applicability to RI (Risks/Liability)***	**RI Risk Summary**
Mass Burn/WaterWall	Unprocessed MSW fired in a chamber built of water tubes. Heat recovered for steam and/or electricity production	The predominant method of WTE in the US and overseas for decades. Over 60 plants currently in commercial operation	Modules up to 750 TPD, with total facility size over 3,000 TPD	High proven reliability, over 90 percent	Air emissions (controlled by statute). Requires residual disposal.	$200k to $300k per installed ton (high)	$40 to $65/ton (moderate) O&M costs. Minimal materials recovery.	Proven commercial technology at appropriate scale. Requires new legislation.	Very Low
Mass Burn/Modular	Unprocessed MSW fired in a series of refractory chambers followed by a heat recovery boiler for steam and/or electricity production	Substantial experience with facilities firing MSW in Europe and to a lesser extent in the U.S.	Modules up to 150 TPD, with total facility size up to 450 TPD	High proven reliability, over 90 percent	Air emissions (controlled by statute). Requires residual disposal.	$150k to $200k per installed ton (moderate)	$50 to $70/ton (high) O&M costs. Minimal materials recovery.	Proven commercial technology; limitations in scaling up to size needed. Requires new legislation.	Low
RDF/ Dedicated Boiler	Shredded MSW, with ferrous metals removed, fired in a chamber built of water tubes. Preprocessing can increase materials recovery.	Dozens of facilities in operation since the 1970's	Modules up to 750 TPD, with total facility size over 3,000 TPD	Good proven reliability, over 80 percent	Air emissions (controlled by statute). Requires residual disposal.	$158k to $198k per installed ton (moderate)	$50 to $60/ton (high) O&M costs.Good materials recovery revenue potential.	Proven commercial technology at appropriate scale. Requires new legislation.	Low
RDF/Fluid Bed	Shredded MSW fired in a sand bed. Preprocessing can increase materials recovery.	One facility firing MSW in the US, other units in Europe and Japan	Facility size up to 460 TPD	Good proven reliability, over 80 percent	Air emissions (controlled by statute). Requires residual disposal.	High capital cost	High O&M costs. Good materials recovery revenue potential.	Proven technology; limited U.S commercial experience; scalability an issue. Requires new legislation.	Moderate
Pyrolysis	Heated MSW in oxygen-starved environment produces a fuel gas that is incinerated to generate usable energy - steam and/or electricity	One pilot plant in California operating for 2 years	Pilot plant sized for 50 TPD MSW	Insufficient experience to establish reliability estimate	Air emissions (controlled by statute), Odors from MSW transport. Residue may have beneficial use.	High capital cost	High O&M costs	High risk, uncertain commercial potential. No operating experience with large scale operations. May require new legislation.	High
Gasification	Heated MSW in oxygen-starved environment generates a fuel gas that can be exported for heat or power generation	Two facilities firing MSW in Japan since 1998, 10 small units firing MSW in Europe and Asia	Multiple modules of 300 TPD MSW each	Insufficient experience to establish reliability estimate	Limited air emissions (controlled by statute), potential air emissions when gas is fired. Residue may have beneficial use.	High capital cost (one vendor estimates $235k-$250k/installed ton)	High O&M costs	Limited operating experience at only small scale. Subject to scale-up issues.	High
Anaerobic Digestion	Extensively preprocessed/Shredded MSW directed to a series of digesters for gas generation that can be exported for heat or power generation	One facility in operation in Israel for less than two years; other limited facilities in Europe	Operating facilities up to 300 TPD	Insufficient experience to establish reliability estimate	Odor, potential air emissions when gas is fired. Residue may have beneficial use.	Low capital cost	High O&M costs. Several materials revenue streams may be available,	Limited operating experience at small scale. Subject to scale-up issues.	High
Mixed-Waste Composting	Shredded and screened MSW is aerated, allowing natural organisms to convert waste into a soil amendment. No energy products are generated.	Hundreds of small plants in operation in Europe; 14 the US, mostly less than 120 TPD	Up to 250 TPD facilities	Product quality unreliable	Odor; potential for product contamination from MSW toxics	Low capital cost	Low O&M costs. Questionable product quality threatens project economics	No large-scale commercially viable plants in operation.. Scale-up an issue.	Moderate to high
Plasma Arc	MSW heated by a plasma-arc in oxygen-starved environment produces a fuel gas that is incinerated to generate usable energy for steam and/or electricity. Similar to gasification.	Two pilot plants in operation since 1999 in Japan	Less than 200 TPD MSW	Insufficient experience to establish reliability estimate	Air emissions (controlled by statute). Residue may have beneficial use.	Very high capital cost	Very high O&M costs	No commercial experience to date. Subject to scale-up issues. May require new legislation.	High
Chemical Decomposition	The organic portion of MSW is heated, converted to a gas, and the gas is refined to water, burnable and non-burnable fractions	No operating plants at this time	No operating facilities at this time	Insufficient experience to establish reliability estimate	Odor, potential air emissions (controlled by statute) when gas is fired	Moderate capital cost projected	Unknown at this time	Technology under development. Not a commercial option at this time.	High

* Does not include risks related to procurement, such as vendor quality and deep-pockets (ability to provide technical, construction and operating guarantees; underwrite risks, etc.)

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