A Review of the Massachusetts Regulated Waste Disposal Industries Focusing on Transportation Emissions

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Executive Summary

Over-road travel associated with the disposal of state-regulated non-hazardous waste results in the generation of greenhouse gas emissions (GHG) through fuel consumption. Specifically, in Massachusetts, various factors have caused a reduction in appropriate disposal locations; this has resulted in increased travel distances and GHG emissions from additional fuel consumption. This study seeks to confirm and quantity this increase over the last ten years, identify trends based on the data, and make recommendations on how to reduce continued increases in the coming years.

This report first provides background on this issue specific to Massachusetts and lays out the two primary research questions as the goals of the study. A substantive literature review is provided to give context of vehicular GHG emissions research conducted by others that could be considered semi-analogous to this study. Traditional disposal methodologies in Massachusetts are then discussed to provide a framework in which the study results can be evaluated.

The Materials & Methods section discusses the reasoning behind limiting the project scope to Massachusetts and the derivation of carbon dioxide (CO_2) data, as well as the actual data analysis. Specific assumptions are explained, and limitations addressed; these show that the derived CO_2 emissions data is a conservative approximation for the industry sector and that a broader analysis (if possible) would have yielded observations of even greater increases in CO_2 generation.

The study results show significant year-over-year increases in CO_2 emissions generation from the transportation of regulated non-hazardous waste in and around Massachusetts as the number of available disposal locations have declined. This trend is most significant for wastes being generated within the Massachusetts Department of Environmental Protection's (MassDEP) Northeast and Southeast regions. This is further amplified by the movement of wastes out of Massachusetts to locations in other states, most commonly Maine and New Hampshire, with New Hampshire representing an ever-growing portion.

While the emissions associated with travel to landfills in Massachusetts have increased substantially over the course of the study period, the number of landfills accepting MassDEP Bill of Lading (BOL) waste have shrunk. The percent of CO_2 emissions from materials going to Massachusetts landfills has also shrunk, even as the number of miles travelled to landfills has increased. By way of example, the CO_2 emissions from wastes generated in MassDEP's Northeast region from traveling to landfills increased from 965.32 metric tons in 2013 to 1,561.80 metric tons in 2019; this represents a 62% increase in CO_2 although the number of loads shipped only increased by 40%.

The landfill findings dovetail with increased travel to asphalt batching facilities as a disposal option while the number of such facilities accepting these wastes have significantly reduced. Detailed analysis of emissions generated through travel to asphalt batching facilities was conducted since such facilities are few in number. Alternate destination scenarios are provided to give context on how continued reduction in this disposal sector niche exacerbates CO_2 travel emissions.

The study found that the dramatic increase in travel to out-of-state disposal locations has significantly increased CO_2 travel-related emissions and represents a growing trend. For reference, the study identified a 564% increase in CO_2 emissions from transport of wastes out of Massachusetts when comparing 2013 to 2019 and a 175% increase when comparing 2018 to 2019.

Although wastes being taken to locations in Maine has slowed (dropping from 4,696 loads in 2018 to 1,819 in 2019, representing a 65% decrease in CO_2 emissions), waste being taken to New Hampshire has increased substantially. A 71% increase in loads taken to New Hampshire between 2018 and 2019 has resulted in a 70% increase in CO_2 emissions during the same period. The largest contributor of wastes going to New Hampshire was found to be sites in MassDEP's Northeast Region, followed by Southeast Region.

Given the trends identified in the study, several recommendations aimed at reducing the generation of CO_2 from transporting regulated wastes are made. Specifically, additional uses for these wastes via asphalt batching should be identified since they are not suitable for the current Massachusetts Department of Transportation (MassDOT) roadway pavement specifications. Inactive but not yet closed landfill locations should be reviewed and the best candidates for reactivation identified; ideally these would be easily accessible locations most advantageously positioned in each MassDEP region to minimize emissions. This should be done in conjunction with identifying new locations that can be utilized as landfills, outfitting them with the current most environmentally beneficial designs and technologies during planning and development. The report also recommends the development of a thermal desorption facility in Massachusetts aimed to reducing the material currently being taken for thermal desorption in New Hampshire, as well as looking to utilize mobile units of the same technology for very large projects. Note that these recommendations are in addition to the continuation potential expansion of MassDEP's Reclamation Project program.

The report concludes that significant CO_2 emission increases have resulted from the remediation of sites as required by state and federal regulations as in-state options have declined. The current increasing trend runs counter to Massachusetts' commitment to moving toward carbon neutrality. This externality is an important point to both address and correct.

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Introduction

The Law of Conservation of Energy states that energy is neither created nor destroyed; it merely changes form. Similarly, mass is conserved when repurposed in such a way to preserve its form as close to its original manner as possible. To that end, all waste materials are cleaned so that they are no longer considered "wastes", are repurposed through recycling processes that change the forms of wastes or are reused in their original physical states. The primary change that wastes undergo in advance of transformation is moving to the physical location for rendering these transformations, shifting location from generation to disposal.

The U.S. Environmental Protection Agency (EPA) defines hazardous waste as "waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment" (EPA, 2020); the EPA defines specific characteristics that render wastes hazardous (ignitability, corrosivity, reactivity, and toxicity) (EPA, 2020). State-regulated non-hazardous wastes are those that still require specific handling and disposal practices and are of particular interest on a state level (although considered non-hazardous by the EPA). In the case of either hazardous or non-hazardous state-regulated wastes, these materials must be taken to permitted facilities for proper handling of the transformation process. Such facilities can include (but are potentially not limited to) liquid treatment facilities, landfills, thermal desorption plants, reclamation sites, and asphalt batching plants; all of these have been encountered in the performance of this study.

Facility locations are often determined by land use considerations on state and local levels, corporate financial decisions, and public pressure. In the case of marginalized communities, there is frequently a lack of public voice and ability to apply pressure (note that the landfills, processing facilities, and other disposal options encountered through this study have generally not been in areas with significant marginalized populations). However, siting choices, financial considerations, and public sentiment seldom consider the externalities wrought decisions made.

In the case of waste disposal facility siting, one such externality is the greenhouse gas (GHG) emissions produced by moving wastes from the generation site to the disposal location. The author has observed and will show through the following discussion of this study's findings that contraction within the disposal industry has increased travel distances between generation points and appropriate disposal/treatment locations. This increase in distance results in additional fuel consumption which, in turn, results in increased GHG emissions from the transportation sector. This paper seeks to explore this issue and reveal unanticipated trends created by positioning decisions that could be considered contrary to current public and private sentiments surrounding GHG emissions. To that end, the following questions will be explored:

- Does the reduction in the number of disposal facilities result in an increase in vehicular emissions because of increased travel distances?
- What methods can be used to mitigate emissions from transportation and/or disposal of wastes in this industrial sector?

This study uses Massachusetts specifically to answer these questions. These are particularly relevant in Massachusetts since, as will be seen, the number of disposal location options has declined in the past decade. The trend was well-recognized and of concern as early as 2013 when the Massachusetts Licensed Site Professional Association (LSPA) and the Environmental Business Council of New England (EBC) hosted the event: "The Crisis of Soil Management for Development Projects in Massachusetts" in November of that year (EBC, 2013). The LSPA wrote to the Commissioner of the Massachusetts Department of Environmental Protection (MassDEP) on this issue on October 11, 2018; in that letter, the LSPA stated:

> "The LSP Association (LSPA) is adding its voice along with other stakeholders who are in touch with MassDEP regarding the need for new disposal options for soils currently regulated and managed under the COMM-97-01 policy. The LSPA encourages MassDEP to convene a discussion group or another forum to consider short-term approaches to addressing this pressing issue, and to develop and implement a long-term strategy for managing contaminated soils within the commonwealth on an expedited schedule.
>
> LSPA members are concerned that disposal capacity at unlined, licensed landfills is already limited, and that the situation will worsen quite soon." (LSPA, 2018)

This study seeks to evaluate whether Massachusetts regulated wastes are being handled in such a way that transportation GHG emissions are minimized; to that end, wastes transported under the MassDEP Bill of Lading form (MassDEP BOL) will be reviewed and discussed. Essentially, this centers the geographic focus of this study on Massachusetts and its surrounding states; however, the general findings can likely be extrapolated to other areas or states where similar phenomena are occurring. In order to identify trends, BOLs finalized and submitted to the Department over the last ten-year period will be analyzed based on the waste generation location, final disposal location, and the distances in between.

Increased transportation distances create many other externalities that are deliberately not considered in this paper. These include (but are not limited to) criteria air pollutant emissions, increased costs pertaining to labor and equipment charges, more rapid aging of vehicles from increased use over decreased time, traffic considerations, roadway maintenance, potential increase of accidents, and federal DOT-related labor issues. All of these issues are worthy of significant consideration but are purposely excluded from this particular analysis.

The following sections review literature pertaining to vehicle GHG emissions or the lack thereof, provide background on Massachusetts' waste tracking process, and discuss the methodologies used in the study. The generated data is then discussed as it relates to Massachusetts in-state and out-of-state disposal trends that have been revealed. Finally, the study makes recommendations for reducing GHG emissions based on these identified trends.

Literature Review

Passenger vehicle and light truck GHG emissions are and have historically been the focus of a significant portion of vehicular emissions research. Dallmann et al (2013) wrote that emissions from these medium to heavy duty vehicle classes has been assumed to be less than those from light duty; however, as we have seen light duty gasoline emissions decline, the emissions loading from medium duty trucks has become clearer. Indeed, the study based on the Caldecott Tunnel in California found:

> "… diesel vehicles (mostly medium-duty delivery trucks with two axles and six tires) accounted for <1% of all vehicles observed in the tunnel but were nevertheless responsible for (18 ± 3)%, (22 ± 6)%, and (45 ± 8)% of measured NOx, OA, and BC concentrations" (Dallmann et al, 2013).

Here "NO" refers to nitrogen oxides and "OA" and "BC" refer to organic aerosols and Black carbon respectively.

The majority of interest in medium and heavy-duty trucks has been in regard to refinement of routes to maximize efficiency in the retail delivery/supply sector to minimize fuel consumption and pollutant emissions (Suzuki, Y., 2011). Dukkanci, Kara, and Bektas most recently build on previous routing and analysis studies performed by independent researchers as well as Unilever (Unilever, 2017), FedEx (FedEx, 2011, 2016), and UPS (UPS, 2015) as recently as 2017 (Dukkanci, Kara, & Betkas, 2019). They discuss the "Green Location-Routing Problem" (GLRP), which combines location routing and pollution-routing and provide both an exact and heuristic solution in order to derive a comprehensive methodology for facility siting and tip routing to minimize depot location operating cost, fuel costs, and CO_2 emissions

(Dukkanci, Kara, & Betkas, 2019). Using the developed algorithmic models, the paper finds that depot locations and routing must be jointly considered to maximize cost benefit and minimize environmental impact, more flexible delivery schedules have positive effects on distances and speeds translating (translating to costs and emissions considerations from fuel consumption volumes), and facility siting focusing on where heavy loads are projected to be delivered on a more common basis could be beneficial (Dukkanci, Kara, & Betkas, 2019).

Efforts have also been made to identify ways in which highway design can be best undertaken to minimize the CO_2 emissions from heavy-duty trucks. For instance, increasing roadway curve radii to 550 m decreased CO_2 emissions (Zhang et al, 2019). However, this does little to mitigate CO_2 emissions when the start and end locations vary between dense urban, suburban, and remote rural environments with long-standing infrastructure that cannot be changed without significant displacement of residential and commercial populations.

Clark et al. (2002) reviewed emissions from heavy-duty vehicles from several angles. Their technical paper considered vehicle class and weight, various driving test cycles, the purpose and local driving patterns of heavy-duty vehicles, the use of different fuel types (i.e. conventional diesel versus reformulated or biodiesel, and various additives), treatment of exhaust prior to ambient discharge, age, terrain, and injection timing (Clark et al, 2002). Their study specifically used particulate matter and nitrogen oxides (PM and NO_x) to demonstrate their findings. The study found that the parameters with the largest effects on emissions were test cycles (1800% on PM and 300% on NO_x) followed by age (1200% on PM and 250% on NO_x); it is worthwhile noting that terrain also affected NO_x emissions by a calculated 250% and PM by 300% (Clark et al, 2002). This would appear counter to the finding of Zhang et al. (2019) since roadway curves would be considered a terrain component unless PM and NO_x cannot be used as overall indicators of GHG emissions and each emissions component must be reviewed discretely. In the case of this current study, CO_2 is the only parameter evaluated and is used as an overall indicator.

The practice of restocking a truck with another load for the return trip is commonly referred to as "backhauling". Backhauling can reduce vehicle emissions if the effort does not result in redirection or "detours" that essentially increase the on-road time (Turkensteen, M. and Hasle, G., 2017). Although this study focused on freight, it is somewhat analogous in that the redirection of MassDEP BOL managed waste to alternate disposal locations is contraindicated by overall efforts within Massachusetts specifically to reduce GHG emissions. The inability to backhaul material in situations like those on which this study is based further exacerbates the GHG emissions scenario.

Both researchers and industry also actively seek improvements in the efficiency of vehicles. The "21st Century Truck Partnership" (21CTP) purpose is:

> "accelerate the introduction of advanced truck and bus technologies that use less fuel, have greater fuel diversity, operate more safely, are more reliable, meet future emission standards, and are cost effective" (21CTP, 2013) (NRC. 2015)

21CTP itself is a collaborative of federal, commercial, and research partners. The focus of their work is developing new technologies for cost-effective, more fuel efficient, and lower emission commercial vehicles, as well as other safety and other considerations (NRC, 2015).

In its most recent review of 21CTP, the National Research Council highlights the attainment of significant milestones in fuel efficiency and GHG emissions reduction goals by the group. These include (but are not limited to) progress in hybrid technologies, power demand improvements requiring significantly less fuel consumption (NRC, 2015).

In summary, significant focus has been placed GHG emissions from vehicles themselves and attempting to find ways to maximize vehicle efficiency. As seen through both Suzuki (2011) and Dukkanci, Kara, and Bektas (2019), attention paid to reducing GHG emissions by minimizing distance travelled has centered on the retail and supply sectors through distribution hubs and maximizing efficiency of vehicle routing; this still places the primary focus on the vehicle. This study focuses on destination since the origination points cannot be predicted. The lack of research directly analogous to this study sheds light on an arena to which more attention should be paid: transportation GHG emission generation beyond the control of the vehicle itself.

Background

This section provides information about the Massachusetts regulated waste disposal industry and provides context for the discussion of study results.

Landfill & Incineration

According to data available through the Massachusetts Department of Environmental Protection Bureau of Waste Prevention's Solid Waste Program, in 2018 there were twenty active landfills in Massachusetts (MassDEP, 2018). A summary of these landfills is provided in **Table One**.

Table One
Active Massachusetts Landfills as of 2018
(MassDEP, 2018)

Name	Town	Type	Active Timeframe	Lined (Y/N)	Permitted Tons/Day	Annual Permitted Tons
Specialty Minerals – Notch Rd	Adams	Sludge	1996-2019	N	600	60,390
Bondis Island	Agawam	Ash	1998 – 2023	Y	96	103.796
Barre Landfill	Barre	MSW	1968 – 2015	Y	300	Not Published
Bourne Landfill	Bourne	MSW	1968 – 2025	Y	700	215,838
Carver Marion Wareham Ash Landfill	Carver	Ash	1975 – 2020	Y	600	55,280
Chicopee Landfill	Chicopee	MSW	1967 – 2018	Y	1,200	209,850
Crapo Hill Landfill	Dartmouth	MSW	1995 – 2029	Y	425	102,106
Allied Services	Fall River	MSW	1938 – 2014	Y	1,950	1,950
Ward Hill Neck Landfill	Haverhill	Ash	1981 – 2022	Y	555	133,708
Hull Landfill	Hull	MSW	1969 – 2018	Y	99	441
Middleborough Landfill	Middleborough	MSW	1963 – 2031	Y	173	58,040
Nantucket Landfill	Nantucket	MSW	1940 – 2017	Y	50	2,800
Peabody Ash Monofill	Peabody	Ash	1996 – 2024	Y	700	Not Published
Wheelabrator Saugus Landfill	Saugus	Ash	1995 – 2017	N	400	113,511
Shrewsbury Landfill	Shrewsbury	Ash	1987 – 2028	Y	770	369,485
Brayton Point Energy	Somerset	Ash	1965 – 2020	Y	295	Not Published
Southbridge Landfill	Southbridge	MSW	1980 – 2018	Y	1,500	325,889
Sturbridge Landfill	Sturbridge	MSW	1973 – 2030	Y	49	275
Taunton Landfill	Taunton	MSW	1938 – 2020	Y	685	119,072
Fitchburg Westminster Landfill	Westminster	MSW	1971 – 2024	Y	1,425	Not Published

Annual Permitted Tons expressed as "Short Ton" or 2,000 lbs
** Active Timeframe represents the year facility operations began to anticipated year of cessation based on the most recent annual report
MSW = Municipal Solid Waste

In total, these twenty landfills represented the disposal of 1,870,481 tons (with a ton being 2,000 lbs) of material annually. Note that whether the list is actually complete is questionable based on the exclusion of the Clinton Landfill in Clinton, MA, from the document; further discussion will show that the Clinton Landfill was a significant disposal resource as late as 2019.

In addition to landfills, Massachusetts also had seven active combustion facilities in 2018 (MassDEP. 2018) which handled 3,254,449 tons of waste. These are listed in **Table Two**.

Table Two
Active Massachusetts Combustion Facilities as of 2018
(MassDEP, 2018)

Name	Town	Year Opened	Permitted Tons/Day	Annual Tons
Covanta Springfield Resource Recovery	Agawam, MA	1988	360	125,937
Covanta Haverhill Waste to Energy	Haverhill, MA	1989	1,650	597,563
Wheelabrator Millbury	Millbury, MA	1988	1,500	463,422
Wheelabrator North Andover	North Andover, MA	1985	1,500	445,288
Pittsfield Resource Recovery	Pittsfield, MA	1981	240	84,854
Semass Resource Recovery (Covanta)	Rochester, MA	1989	5,800	1,119,630
Wheelabrator Saugus	Saugus, MA	1975	1,500	417,755

Permitted Tons and Annual Tons expressed as "Short Ton" or 2,000 lbs

Over time the number of available locations for disposal of state-regulated wastes has diminished substantially. During the period of this study (2010 – 2019), a total of eighty-four (84) landfills were rendered inactive and fifteen were closed; three of the landfills closed during this time have been capped and the rest are listed as complete (MassDEP, 2018). **Table Three** breaks these down by year.

Note that, in **Table Three**, the (#) after the year under "Closed Year" represents the number of landfills truly permanently closed in that year. For example, regarding 2010, eighteen landfills became inactive. Of those eighteen, four are permanently closed; three of the closures occurred in 2011 and one in 2013.

Table Three
Inactive Landfill Statistics
MassDEP, 2018

Inactive Year	# of Landfills	# Closed	Closed Year
2010	18	4	2011 (3)
			2013 (1)
2011	6	4	2012 (2)
			2014 (1)
			2016 (1)
2012	10	2	2015 (1)
			2016 (1)
2013	9	0	N/A
2014	9	3	2014 (1)
			2015 (1)
			2016 (1)
2015	9	1	2015 (1)
2016	11	1	2016 (1)
2017	8	0	N/A
2018	3	0	N/A
2019	1	0	N/A

Note that the landfill that is listed as Inactive Status in 2019 is the Specialty Minerals Combined Notch Road Landfill included as active on the 2018 list.

Although only fifteen landfills that were rendered inactive during this period have been closed (none of which have closed in the past three years), it could be presumed as likely that they will not return to permanent active status.

Asphalt Batching

Historically, one of the primary methods of disposing of soils and sludges has been through reusing the material in the production of asphalt; other materials such as asbestos, construction debris (brick, concrete, etc.) or fabric-based soils cannot be disposed of by this method. Material has been accepted by select asphalt batching plants as long as it falls within certain chemical and physical parameters allowed under a facility's permit, as documented by chemical and material analysis by a certified laboratory. The following list disposal profiling requirements is from Ondrick Materials & Recycling (Ondrick, 2019), but are representative of other parameters currently and historically required by other facilities. These parameters include:

- Total or Extractable Total Petroleum Hydrocarbons (TPH/ETPH/EPH)
- Volatile Organic Compounds (VOCs)
- Chlorinated Solvents
- Flashpoint
- pH
- Reactivity (Sulfide and Cyanide)
- PCBs
- RCRA 5 Metals (Arsenic, Cadmium, Chromium, Mercury, Lead)
- Total Organic Carbon (TOC)

Note that Ondrick has mass limits for TPH, VOCs, Chlorinated Solvents, PCBs, metals, and TOC; pH has an acceptable range, flashpoint must be above 140º F, and the material must be non-reactive (Ondrick, 2019).

In Massachusetts, three companies operating multiple locations have historically accepted MassDEP BOL soils at their asphalt batching plants between 2010 and 2019 (the study years); this has been enumerated through the review of the publicly available MassDEP BOLs. These companies were Aggregate Industries (multiple locations), Brox Industries (multiple locations), and Ondrick Materials & Recycling (single site). However, over the years covered by this study, Aggregate Industries closed their facilities to the point of not receiving any additional impacted soil going forward (Aggregate Industries email correspondence, multiple years; S. Wood personal discussions, multiple years) and Brox Industries reduced from two locations to one (S. Wood personal discussions, 2020). This is presumed to have placed additional pressure on landfills and resulted in additional transportation challenges.

Liquid Disposal

State-regulated liquid waste treatment facilities are limited in Massachusetts. Only two were encountered over the course of this study. This indicates a lack of options available for disposal; any problems with these types of facilities would, by default, place additional pressures on waste transportation.

As an example of this, NewStream, LLC of Attleboro, MA, was established in 2005 for the treatment and/or disposal of non-hazardous industrial water and wastewater, as well as antifreeze and used oil (Manta.com, nd). However, the facility was closed in 2013 due to odor issues associated with its operations (Rhodes, 2013). At this time, the "only fully permitted industrial/commercial wastewater treatment/recycling facility in Massachusetts" (Globalcycle, nd) as a disposal option is Globalcycle, Inc., of Taunton, MA, in collaboration with Covanta.

Materials & Methods

Data Collection

A significant amount of data pertaining to the transportation of soil, water, and other wastes is available in the public sphere; for the purposes of this discussion, other wastes are considered to be those classified by EPA (as previously referenced) as "hazardous", regardless of their composition. Individual states require the tracking of shipments to ensure the proper handling of materials, compliance with applicable permits by transporters and disposal facility locations, and the proper final disposition of wastes in accordance with Resource Conservation and Recovery Act (RCRA) provisions. This is most commonly done through the submission of manifests and/or Bills of Lading to the appropriate generation and destination state agencies.

Massachusetts

<u>Background</u>

In the case of Massachusetts, the Massachusetts Department of Environmental Protection (MassDEP) developed form BWSC-012, subparts A, B. and C (MassDEP BOL). BWSC-012A contains the appropriate tracking number, site address, generator information, transporter information, and disposal facility address, among other information not relevant to this project. Subpart B is a load sheet on which all loads being transported under that BOL are recorded; note that multiple BOLs can be generated for one location but each individual load is discreet to a particular BOL. Subpart C is the final certification by both the generator and the disposal facility that all transportation of loads under that BOL is complete. Note that this document set must be used for all state-regulated wastes originating in Massachusetts; as a result, information about material generated in Massachusetts but being disposed of out of state is available through these documents.

In 2010, MassDEP instituted mandatory on-line filing of Bills of Lading. The process does require the initial BWSC-012A to be submitted multiple times with different levels of information. However, the final information required for this study [i.e. the load sheets (BWSC-012B)] is available when the finalized MassDEP BOL documents are uploaded. This information is entirely searchable and viewable through MassDEP's on-line portal (MassDEP, nd).

Note that finalized MassDEP BOLs may include information about shipments that crosses over a year. For example, a finalized MassDEP BOL uploaded in January of 2018 many include shipments from the fourth quarter of 2017. This study looks at the emissions profiled by the MassDEP BOLs themselves, not the specific dates of transport.

Collection Approach

Data collection for Massachusetts consisted of inspecting all Bills of Lading finalized within specific years. Originally, the intended years were 2003, 2008, 2013, and 2018. However, the MassDEP BOLs for 2003 and 2008 were not found to be readily accessible from a single repository; prior to the on-line filings, BOLs were submitted as disposal documentation within individual reports for listed sites. This resulted in reduction of the originally intended data set.

It was deemed prudent to inspect other years from the time of the online program's development. The program was implemented in 2010, with the first completed MassDEP BOLs being submitted in November 2010; a total of twelve finalized MassDEP BOLs were submitted by the turn of that year. It was decided to review MassDEP BOLs that were finalized in 2011 because of the observed lack of 2010 data. In order to create an even more robust data set and solidify observations of trends, MassDEP BOLs finalized in 2013 were then reviewed. 2018 MassDEP BOLs were reviewed as originally intended. January 1, 2020, marked the closure of the 2019 dataset, so that year's completed MassDEP BOLs were reviewed, as well.

For each MassDEP BOL inspected, the Release Tracking Number [RTN (unique identifier by which a site is tracked by MassDEP)], Site Address, Disposal Facility Address, and number of loads per BOL were recorded. Using the www.calculator.net (Maple Tech International, 2008) program available on-line, the mileage between the Site and Disposal Facility was calculated. This was then multiplied by two to determine the extended miles (Ext. Miles); the reasoning behind this approach will be discussed in the **Assumptions & Limitations** section to follow.

Other Northeastern States ~ Limiting of Project Scope

The original intent of this study was to review emissions data through transport of waste throughout New England, New York, and New Jersey. Inquiries were made through telephone discussions and/or Freedom of Information (FOI) requests to the Connecticut Department of Energy and Environmental Protection (CT-DEEP), Rhode Island Department of Environmental Management (RI-DEM), New Hampshire Department of Environmental Services (NH-DES), and New York Department of Environmental Conservation (NY-DEC) for copies of Hazardous Waste Manifests, Non-Hazardous Waste Manifests, and any relevant Bills of Lading. New Jersey information was found to be available online.

It quickly became apparent that, generally, no Non-Hazardous or Bill of Lading documentation would be available on a state level and any such documentation would need to be obtained from individual facilities; in the event that a facility was closed, that information would be unattainable. Additionally, difficulties with the New Jersey online database prevented accessing any information from that state regarding manifests, Hazardous or Non-Hazardous.

In discussion with the author to clarify the scope of the FOIL request (S. Wood personal discussion, 2019), NY-DEC stated that the scope of the request was too large and would only send documentation for the seven largest Treatment, Storage, or Disposal Facilities (TSDFs) currently active in the state; no historic landfill operation data was available nor was information from TSDFs that were no longer operational.

Connecticut DEEP did have Hazardous Waste Manifest information available through two formats covering the requested years of 2003, 2008, 2013, and 2018. Because of the volume of data, primary analysis was limited to manifests for in-state shipment only. This dataset was reviewed according to the same methodology described above for the Massachusetts Bills of Lading: Site Location, Facility Address. Unlike the MassDEP BOLs, each manifest represents a single, independent shipment; the mileage between the two points was calculated as a distinct trip. The results could then be extrapolated based on a comparison to the number of CT-Out-of-State-Load increases. After working with CT-DEEP online data, a significant amount of new data was uploaded for years under review (2013 and 2018). Based on this, it was clear that the Connecticut dataset was in flux rather than fixed. Any conclusions derived from it would be questionable and the decision was made to focus on Massachusetts only.

Deriving Carbon Dioxide Emissions Data

Vehicle Type ~ Class D Trucks

The Federal Highway Administration classifies vehicle types based on various criteria. Regarding trucks, the body construction, number of axels, and gross vehicle weight (GVW) largely dictate the classification. Class 8 trucks are those with four or fewer axles and a single trailer (FHWA, nd) and also have:

> "a GVWR of greater than 33,001 pounds or 14,969 kilograms and includes all tractor-trailers"(Murray, 2019)

The majority of vehicles involved with the transport for disposal of the wastes in question would be classified as Class 8.

In order to derive the amount of carbon dioxide generated by a Class 8 vehicle in transit, it was necessary to identify the average fuel efficiency of a Class 8 vehicle. According to the U.S. Department of Energy's gathering of statistical analysis, 5.29 miles per gallon is the average consumption rate (USDOE AFDC, nd). This is the MPG used in the analysis.

Data Analysis

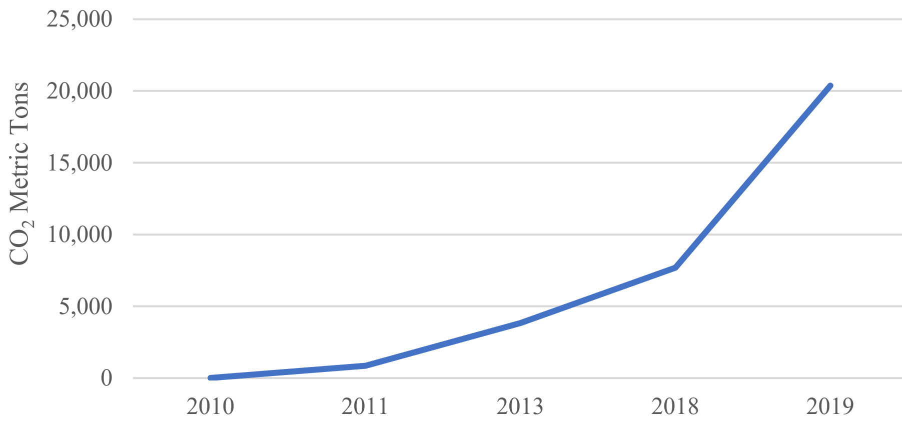
The author-derived Ext. Miles were used as the base factor for calculation. By dividing the number of miles per trip by the MPG described above, a solid approximation of the gallons of fuel used in transit could be calculated. The Ext. Miles for each document was divided by the MPG to derive the gallons consumed. 22.0242 lbs. CO_2/gal is used in this study as the amount of CO_2 generated by the combustion of one gallon of diesel fuel (McLean, 2017).

Once the lbs of CO_2 per BOL and manifest was calculated, these volumes were converted to metric tons. The years were then compared with each other in order to identify trends. The Massachusetts BOL data is documented in **Table Four** and a graphical representation is provided as **Figure 1**.

Table Four
MassDEP BOL CO_2 Emission Tonnage

	2010	2011	2013	2018	2019
Total Ext. Miles	8,857.4	506,457.2	2,261,879.6	4,537,433.2	12,022,530.38
Class 8 MPG diesel	5.9	5.9	5.9	5.9	5.9
Gal diesel consumed	1,501.3	85,840.2	383,369.4	769,056.5	2,037,717.0
lbs CO_2/ gal	22.0242	22.0242	22.0242	22.0242	22.0242
Total LBS CO_2	33,063.92	1,890,561.81	8,443,404.86	16,937,853.61	44,879,087.06
Total Metric Tons	**15.01**	**858.32**	**3,833.31**	**7,689.79**	**20,375.11**
% increase	***N/A***	***5,618%***	***347%***	***101%***	***165%***

Figure 1
MassDEP BOL CO_2 Metric Tons



Assumptions & Limitations

There are a series of assumptions and limitations inherent in this analysis, but none are significant enough to potentially nullify any findings. Discussions of each are provided below.

Exclusion of MassDEP BOLs for Limited Removal Actions (LRAs) and MassDEP Material Shipping Records

<u>*Massachusetts Reporting Conditions & LRAs*</u>

The MassDEP BOLS discussed in this study are those that have been filed with MassDEP for listed/tracked sites. A location becomes a listed site by falling into one (or sometimes more) reporting condition. Abbreviated citations from 310 CMR40.00, the Massachusetts Contingency Plan (MCP) (Massachusetts, 2014 *revised*) are provided below to provide context. The full descriptions can be found in the MCP as referenced.

- 2-Hour Reporting Condition (310 CMR 40.0312):
  1) A release or threat of release to the environment of oil and/or hazardous material (as described elsewhere in 310 CMR 40.00) that would be equal to or greater than the applicable Reportable Quantity (RQ)
  2) a release or threat of release (regardless of quantity) that does or could constitute an Imminent Hazard, as described by310 CMR 40.0321.
- 72-Hour Reporting Condition (310 CMR 40.0313)
  1) Discovery of a release to the environment by the observation of Nonaqueous Phase Liquid (NAPL) at a measured thickness lens of 0.5” in a monitoring, excavation, or subsurface structure more than 30’ from a school, daycare, or occupied residence

2) Discovery of a release to the environment through the observation of oil and/or hazardous material within 10’ of an underground storage tank (UST) via observed total organic vapor (TOV) concentrations greater than or equal to 100 parts per million (ppm) as benzene through headspace screening methods more than 2’ below surface grade and as part of closure assessment in accordance with 527 CMR 9.00 and 40 CFR 280-201 or the removal or closure of a regulated UST
3) Discovery of a release via observed groundwater concentrations greater than or equal to RCGW-1 Reportable Concentrations within a public water supply Zone 1 or within 500’ of a private water supply well
4) A Substantial Release Migration (SRM) condition as defined by 310CMR 40.0313 (4a-f) associated with a release that currently or previously has met notification conditions

A Threat of a 72 Hour Release as defined by 310 CMR 40.0314 also requires notification.

- 120-Day Reporting Condition (310 CMR 40.0315)
  1) A release to the environment indicated by the measurement of one or more hazardous materials in soil or groundwater in an amount equal to or greater than the applicable Reportable Concentration (RC) listed in the Massachusetts Oil and Hazardous Materials List [MOHML (310 CMR 40.1600)]
  2) A release to the environment indicated by the measurement of oil and/or waste oil in soil in an amount equal to or greater than the applicable RC listed in MOHML where the total contiguous volume of the contaminated soil is greater than or equal to than two cubic yards
  3) A release to the environment indicated by the measurement of oil in groundwater in an amount equal to or greater than the applicable RC listed in MOHML
  4) A release to the environment observed through the presence of NAPL measured between 0.125” and 0.5” in a groundwater monitoring well, excavation, or other subsurface structure

If a 120-Day Reporting Condition can be resolved within the 120 days, reporting is not required. Soil removal in these cases is conducted under Limited Removal Actions (LRAs) as per 30 CMR 40.0318. In these cases, MassDEP BOLs used to move material are maintained by the Generator and the Destination Facility and filing of the documents to MassDEP is not required.

Imported Regulated Waste Shipments

MassDEP Material Shipping Records (MSRs) are documents used to manage shipments of Massachusetts-regulated waste from other states into Massachusetts. Since the origination locations are not being tracked by MassDEP, there are no RTNs associated with the locations and these MSR forms are not available online. A request to MassDEP for information about and copies of these documents was not fulfilled so mileage for these documents was not able to be tracked.

LRA BOLs and MSRs would increase the miles driven and resulting emissions tracked and discussed. The inability to capture this information does not nullify the validity of the information that was able to be gathered. This lack only underscores the fact that the calculations and values derived, and trends identified are a very conservative and limited estimate of GHG projections.

Transporter Origination Location ~ Calculation of Ext. Miles

In the case of each document, MassDEP BOL or manifest, the starting location of the transporter to pick up the load or to end at after the load is dropped is considered an unknown; in the trucking industry generally, this is known as "deadheading" (Business Pundit, nd). This information cannot be fully quantified based on information available in the documents. Transporter information fields on the documents might only provide the headquarters location that a company is licensed from in order to indicate the responsible party for transit. It would not necessarily account for a sub-office/branch or remote garage location. Similarly, it would not account for the use of a subcontractor by the primary transporter based on vehicle availability. Prime examples of this would be when multiple roll-off trucks were mobilized southward post-911, in response to Hurricane Katrina, and in response to the BP Gulf Oil spill; local subcontractors were used to move roll-off containers for disposal during those times (S. Wood personal discussions, multiple years). In situations such as these, the origination and final housing points of vehicles would not be the address listed as the transporter on the document. In order to resolve this limitation, the Ext. Miles number is calculated as the distance both from the generation site to the destination location and the return trip. This assumes that a selected contractor would be within relative proximity to the generation site in order to maintain the highest level of cost efficiency on a project.

Bulking of Loads

In the case of bulk solids or liquids, loads from multiple locations generally must remain discreet. That is, material from multiple sites cannot be comingled in a single roll-off container and liquids from multiple sites are generally not bulked due to characterization limitations. However, in the event of drummed waste, it is possible that one truck could make several stops in a single trip (i.e. a "drum run") and carry drums from multiple discreet locations for a single drop at a TSDF; note that drumming liquids or solids is common when the generated volumes are generally considered to be small and the cost to dispose of drums is less than the cost to dispose in bulk (when accounting for generation method and associated equipment/vehicle costs) (S. Wood personal discussions, multiple years). Without being able to inspect individual transporter daily worksheets or driver logs, this information is not able to be captured.

The same premise used for the Transporter Origination discussion is applicable. Fuel efficiency decreases as the weight of a load increases. The U.S. Department of Energy holds that fuel efficiency decreases 1% per 100 lbs (Fueleconomy.gov, nd). For reference, a 55-gallon drum filled with water weighs 458 lbs; three drums of soil are considered to equate to one cubic yard, generally weighing 1.5 tons. Regardless of cargo type, a vehicle carrying twenty 55-gal drums of waste will weigh more than the same vehicle carrying three and consume fuel at a faster rate, increasing its CO_2 emissions accordingly. The decrease in efficiency is considered a reasonable offset and the Ext. Miles methodology employed is still considered reasonable.

Weather, Traffic, & Demurrage Factors

The distances calculated between generation and destination locations represent a best-case scenario of the optimal route. They do not account for construction rerouting, road closures due to emergency events, or delays in transit that would increase drive time and increase fuel consumption rates. Likewise, several types of vehicles used in the transport of these types of wastes have extended periods of fuel consumption during the loading process inherent in their design; two examples of these would include liquid vacuum trucks and soil/solid vactor trucks, both of which use fuel to power motors to pull the material on board. Even if facilities have instituted policies prohibiting extensive idling, the inefficiency of waiting in off-load lines for extended periods and starting and stopping engines multiple times results in increased fuel consumption and CO_2 emissions. However, these conditions represent temporal externalities that cannot be predicted and/or adequately quantified. They are therefore not considered in this analysis.

Vehicle Maintenance

The condition in which a transporting company maintains its vehicles has a direct effect on the performance of said vehicles' engines. It cannot be known whether individual companies maintained their vehicles in optimum working condition in order to meet the fuel efficiency standards used. However, the overall assumption must be that fleet maintenance meets or approaches appropriate levels and that the MPG rating is generally representative.

Results & Observations

Analysis of the MassDEP BOLs resulted in the identification of multiple trends. These are detailed below.

A total of 2,885 BOLs were reviewed for the years studied. To reiterate, these years were 2010, 2011, 2013, 2018, and 2019. These constituted a total of 19,337,157.78 extended miles as previously described, which equated to 32,771.52 metric tons of CO_2. Over time, the number of BOLs profiling materials staying within Massachusetts decreased. For reference, the breakout of these BOLs are documented in **Table Five**.

Table Five
MassDEP BOL Shipment Destinations

	2010	2011	2013	2018	2019
Total BOLs	***12***	***473***	***793***	***832***	***777***
Total MA - CT	0	1	1	2	0
Total MA-GA	0	0	0	0	1
Total MA - MA	5	306	438	411	342
Total MA - ME	0	48	131	132	60
Total MA-MI	0	0	0	0	1
Total MA - NH	6	111	188	251	317
Total MA-NJ	0	0	0	0	9
Total MA - NY	0	2	1	10	8
Total MA - OH	0	0	2	4	3
Total MA - RI	0	2	22	5	16
Total MA - VT	1	3	10	17	18

As shown, the number of BOLs reviewed for loads staying within Massachusetts decreased from 62.5% in 2013 to 44% in 2019. This coincides with a significant increase in material being transported into New Hampshire: 23% in 2013 versus 41% in 2019.

Based on MassDEP BOL data, in 2019, there were five facilities that received material in New Hampshire. These are listed below.

- Tradebe, 410 Shattuck Way, Newington, NH
- NCES Landfill, 581 Trudeau Road, Bethlehem, NH
- ESMI, 67 International Drive, Loudon, NH
- Four Hills Landfill, 840 West Hollis Drive, Nashua, NH
- Turnkey Landfill, 90 Rochester Neck Road, Rochester, NH

Discussion of Massachusetts Regions

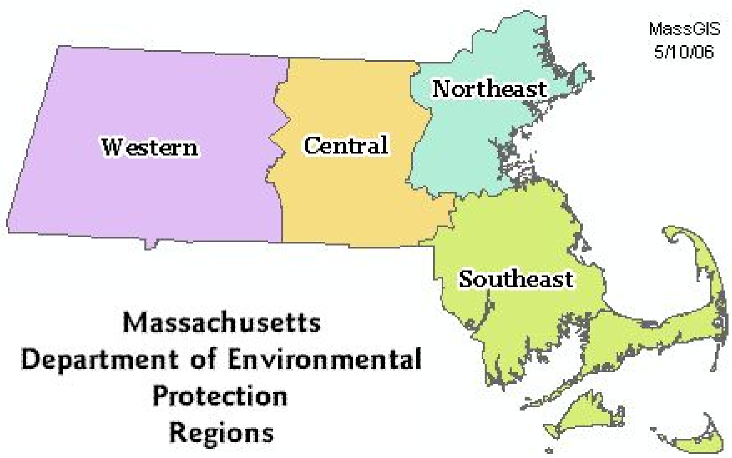
For the purposes of site oversight and management, MassDEP is divided into four regions, each having its own office; the Boston Headquarters office is not one of these. The titles and locations of the offices will be listed in **Table Six**. A visual representation of the Massachusetts and its regions is provided, as well.

Tracked sites are each given a unique identifier known as a Release Tracking Number (RTN). This number begins with the numerical indicator for the region (followed by a hyphen) and a sequential number specific to that region (MassDEP, 2017). For example, there could be a site with the RTN 1-12345 located in Western Region and a site with the RTN 3-12345 located in Southeast Region; these are known to be separate and distinct locations due to the difference in the numerical indicator. In terms of this study, all of the MassDEP BOLs have RTNs associated with them. This allows for analysis of increased traffic coming from various parts of the state.

Table Six
MassDEP Region Descriptions

Name	Location	# of Communities	Numerical Indicator *
Western Region	436 Dwight St, Springfield, MA	106	1
Central Region	8 New Bond St, Worcester, MA	77	2
Northeast Region	205B Lowell St, Wilmington, MA	84	3
Southeast Region	20 Riverside Dr, Lakeville, MA	84	4

* Note the numerical indicator is only the first number of the unique RTN for sites and denotes the region where a site is located.



https://www.mass.gov/files/images/massgis/datalayers/reg-dep.jp

MassDEP BOL From-To Data

The information presented later in this discussion will focus on both issues which affected the regulated waste disposal industry (resulting in contraction) and the effect that this has had on GHG emissions from this industry sector. In advance of this discussion, it is fair to state that the number of available facilities in all MassDEP regions has declined, resulting in increased cross-region and out-of-state transport. This is clearly evident on a BOL-review basis without considering the number of loads associated with each MassDEP BOL. The following **Matrix One** is intended to detail these trends on a per-region basis in advance of more focused discussions on resulting emissions.

Matrix One ~ MassDEP BOL From-To Data

2010 Finalized MassDEP BOL Totals

	W	C	NE	SE	Other
W	ND	ND	ND	ND	2
C	2	3	ND	ND	ND
NE	ND	ND	ND	ND	3
SE	ND	ND	ND	ND	2

W = Western C = Central NE = Northeast SE = Southeast
ND = No Documents

2011 Finalized MassDEP BOL Totals

	W	C	NE	SE	Other
W	78	4	0	0	4
C	7	34	2	8	22
NE	3	23	40	33	121
SE	1	3	1	69	20

W = Western C = Central NE = Northeast SE = Southeast

2013 Finalized MassDEP BOL Totals

	W	C	NE	SE	Other
W	101	1	0	1	15
C	16	14	3	15	40
NE	3	62	23	95	278
SE	2	1	2	95	26

W = Western C = Central NE = Northeast SE = Southeast

2018 Finalized MassDEP BOL Totals

	W	C	NE	SE	Other
W	78	8	0	0	19
C	25	37	1	4	29
NE	16	98	40	55	308
SE	10	4	1	34	65

W = Western C = Central NE = Northeast SE = Southeast

2019 Finalized MassDEP BOL Totals

	W	C	NE	SE	Other
W	49	1	0	0	11
C	43	8	5	0	35
NE	22	93	38	49	315
SE	18	3	1	13	73

W = Western C = Central NE = Northeast SE = Southeast

Figure 2(a)
Western Region From-To MassDEP BOLs

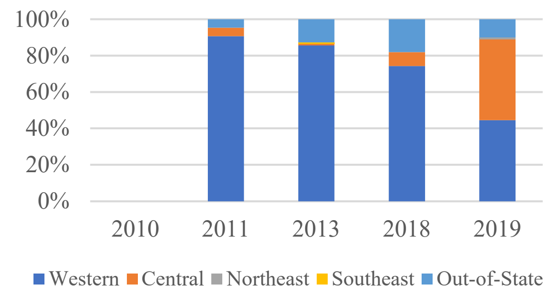


Figure 2(b)
Central Region From-To MassDEP BOLs

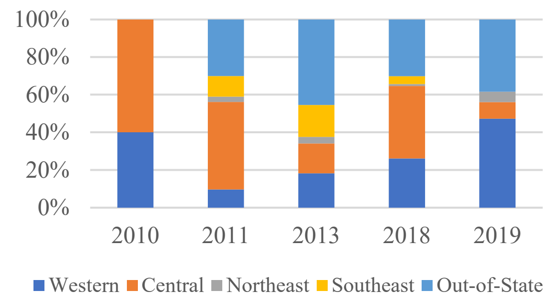


Figure 2(c)
Northeast Region From-To MassDEP BOLs

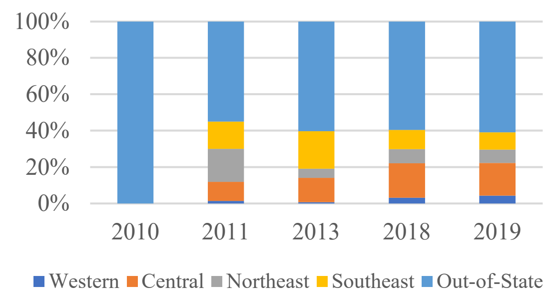
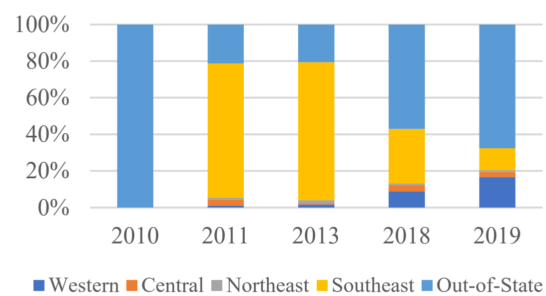


Figure 2(d)
Southeast Region From-To MassDEP BOLs



Massachusetts Landfills

A significant portion of MassDEP BOLs reviewed profiled wastes being taken to landfills. A review of these documents has generated the following information.

Table Seven
Landfill Destination Document & Load Summary

	2010	2011	2013	2018	2019
# BOLs	3	83	159	206	174
# Loads	13	1,880	8,708.00	9,205.00	16,842.72

Although the amount of material going to landfills increased over time, the number of available landfills as destinations reduced, dropping off after 2013. **Table Eight** shows the destination landfills for each year's finalized MassDEP BOLs; the information presented in **Table Eight** was compiled from the MassDEP BOL information reviewed in this study. Note that the 2010 landfill list is likely abbreviated because of the partial year filings.

Table Eight
Mass DEP BOL Destination Landfills

2010	2011	2013	2018	2019
2 Total	***16 Total***	***22 Total***	***15 Total***	***14 Total***
Greenwood St Landfill	Barre Landfill	Bourne Landfill	Barre Landfill	Bourne Landfill
Fitchburg Landfill	Bourne Landfill	Crapo Hill Landfill	Bondi Island Landfill	Clinton Landfill
	Crapo Landfill	CT Valley Sanitary Landfill	Bourne Landfill	Crapo Landfill
	CT Valley Sanitary Landfill	ET&L	Clinton Landfill	CT Valley Sanitary Landfill
	Fitchburg Landfill	Fall River Landfill	Fall River Landfill	Fall River Landfill
	Former Upton Landfill	Fitchburg Landfill	Fitchburg Landfill	Fitchburg Landfill
	Greenwood St Landfill	Former Upton Landfill	Gardner Sludge Landfill	Glenview Landfill
	Haverhill Landfill	Greenwood St Landfill	Glenview Landfill	Hopedale Landfill
	Holyoke Landfill	Haverhill Landfill	Hopedale Landfill	Lynn Landfill
	Middleborough Landfill	Holyoke Landfill	Middleboro Landfill	Middleboro Landfill
	Northampton Landfill	Marblehead Landfill	Peabody Sanitary Landfill	Peabody Ash Monofill
	Southbridge Disposal Park	Middleboro Landfill	Pond Street Landfill	Southbridge Disposal Park
	Stoughton Landfill	New Bedford Reg. Refuse Mgmt	Southbridge Disposal Park	Taunton Sanitary Landfill

Table Eight (Continued)
Mass DEP BOL Destination Landfills

2010	2011	2013	2018	2019
	Taunton Landfill Titcomb Pit Landfill Ward Hill Neck Landfill	Page Street Landfill Pond Street Landfill Portsmouth Landfill Saugus Resco Landfill Shawmut Transfer Station South Hadley Landfill Southbridge Disposal Park Stoughton Landfill Taunton Landfill	Taunton Sanitary Landfill Ward Hill Neck Landfill	Ward Hill Neck Landfill

This reduction in the number of available landfills is seen to have an impact in the number of miles travelled and the resulting CO_2 emissions generated, as shown in **Table Nine**. On a separate note, landfills also often have material and chemical disposal profiling requirements for materials they are asked to accept. However, these can vary depending on the requirements of each individual landfill permit. Generally, the requirements would be similar to those required by asphalt batching facilities at minimum to document that materials do not exhibit characteristics that would render them classified as "hazardous".

Table Nine
Travel to Landfills Emissions Data

	2010	2011	2013	2018	2019
Total Ext. Miles	211.6	142,031.6	614,233.2	672,415.8	1,516,310.78
% Increase Annual Ext. Miles	*Not considered*		332%	9%	126%
Metric T CO_2	0.36	240.71	1,040.97	1,139.57	2,569.76
% of Annual Metric T CO_2	2%	28%	27%	15%	13%

Note that the percent increase in the annual metric tons of CO_2 generated mirrors the percent increase in the annual Ext. Miles year over year.

The above data raises several questions, the first of which is whether or not there is a reason for the tremendous increase in miles travelled as expressed by Ext. Miles when the number of finalized MassDEP BOLs actually dropped between 2018 and 2019.

Twenty-four of the MassDEP BOLs finalized in 2019 were related to the development of the Encore Boston Harbor hotel and casino by Wynn Properties (RTN 3-13341). Under these BOLs, material was taken to six separate landfills. These landfills are listed in **Table Ten**, as well as the respective distance from the project site and the number of loads accepted at each.

Table Ten
Everett Boston Harbor Landfill Destinations

Landfill	Distance from Gen. Site	# Loads
Clinton Landfill	52.1	1,425
Fall River Landfill	51.1	3,705.72
Fitchburg Landfill	57.8	89
Hopedale Landfill	45.7	3
Middleboro Landfill	50.8	111
Taunton Sanitary Landfill	39.7	370

Note that the #.72 was likely a typographical error on the MassDEP BOL load sheet; however, the number of loads on that day was listed as 130.72. The conscious decision was made in gathering and working with the data to assume that the information provided to MassDEP is correct and complete, so the #.72 has been carried over in this analysis.

In total, the transport of the material from the project site to the six landfills totaled 578,427.8 miles as expressed by Ext. Miles. This accounts for the generation of 980.29 metric tons of CO_2 alone, or 38% of the total CO_2 generated by the transport of regulated waste for the year. It is fair to point out, as well, that the acceptance of this much material from one project site moves the individual landfills much closer to reaching capacity faster and therefore creates further strain on disposal of regulated wastes moving forward.

In the absence of the material from the Everett casino project, the CO_2 emissions would have been 1,589.47 metric tons. This would have been a 39% increase over the 2018 CO_2 emissions. This increase is still substantial but certainly not as outsized as what actually occurred.

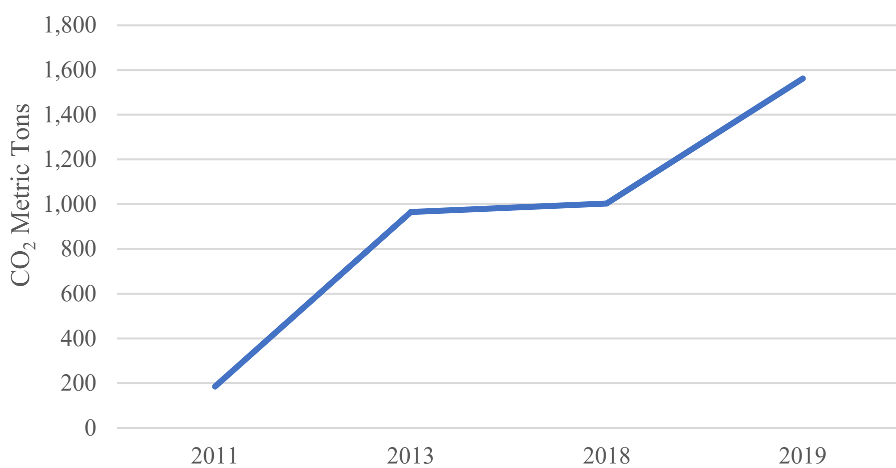
The other trend which has resulted in a substantial increase in CO_2 emissions from regulated waste disposal is material from MassDEP's Northeast Region. Of the twenty landfills active as per MassDEP's list three are located within Northeast Region: Ward Hill Neck landfill, Peabody Ash Monofill, and Wheelabrator Saugus Landfill. However, of the 131 MassDEP BOLs for materials coming from the Northeast Region, only twelve remained within the region, representing 9%. This is a significant change from 2018 when twenty-six, or 16%, of 164 Northeast Region MassDEP BOLs stayed within the region.

Information relative to this trend in Northeast Region is provided below in **Table Eleven** and depicted by **Figure 3**. No material was transported to a landfill in 2010 under MassDEP BOLs available and reviewed.

Table Eleven
Northeast Region Landfill MassDEP BOLs & Emissions

	2011	2013	2018	2019
# MassDEP BOLs	50	132	165	132
Total # Loads	1,261	7,671	7,163	10,751
Total Ext. Miles	109,460.40	569,599.40	592,222.80	921,557.00
Metric T CO_2	185.51	965.32	1,003.67	1,561.80
% of all Landfill Transport CO_2	77%	93%	88%	61%

Figure 3
Northeast Region Landfill Metric T CO_2



This same phenomenon is not replicated in other regions.

Ondrick Discussion

The data has shown that one of the most significant disposal options in Massachusetts is Ondrick Materials & Recycling, LLC (Ondrick). Located in Chicopee, MA, Ondrick is an asphalt batching plant that recycles MA01 waste class (state regulated) petroleum contaminated soil (PCS). It holds a Level III, Class A Hazardous Waste recycling permit issued through MassDEP (Permit # X258844, EPA ID Number MAR000529677) (Ondrick, nd).

MassDEP BOL information for the years studied have been analyzed and the data presented in **Table Twelve** has been generated from that analysis.

Table Twelve
MassDEP BOLs to Ondrick

	2010	2011	2013	2018	2019
Total BOLs	12	473	793	832	777
Ondrick BOLs	2	67	90	106	118
Ondrick % of BOLs	17%	14%	11%	13%	15%
Total Loads	53	4,972	21,093	24,501	40,538
Ondrick Total Loads	17	337	1,016	828	970
% of Total Loads	32%	7%	5%	3%	2%
Ondrick Ext. Miles	1,568.40	19,409.40	36,229.80	70,645.00	125,717.00
Metric T of CO_2	2.66	32.86	61.35	119.62	212.87
Annual Total Metric T CO_2	15.01	858.32	3,833.31	7,689.79	20,375.11
% of Annual Total Metric T	18%	4%	2%	2%	1%

As shown in **Table Twelve**, Ondrick accepts a significant portion of the total wastes (as represented by total loads) shipped under MassDEP BOL annually. Although the number of loads accepted by Ondrick increased substantially from 2011 to 2013, this number actually dropped from 2013 to 2018. This decrease in close to two hundred MassDEP BOLs nevertheless resulting in a near doubling in Ext.Miles between 2013 and 2018. The comparison between 2018 and 2019 finalized MassDEP BOL data is even more startling: the number of MassDEP BOLs to Ondrick only increased by twelve, yet the number of loads increased by 142 during the period which represented a 78% increase in Ext.Miles. A partial explanation for this is the closing of other asphalt batching facilities and landfills, both of which will be discussed later in this report.

Given the number of Ext.Miles traveled to and from Ondrick's facility under MassDEP BOL, it is surprising that the percent of total GHG emissions as measured by CO_2 attributable to Ondrick BOLs is not greater. With the exception of the 2010 dataset, which is known to be flawed because of its temporal brevity, CO_2 emissions from these load trips have never reached 5% of a year's total emissions. Indeed, in 2019, emissions represented by Ondrick-destination BOLs only constituted 1% of the annual studied total. This indicates that a significant portion of recent (and most probably current) CO_2 emissions are being derived from load trips to other destinations.

Maxymillian Discussion

One of the most significant disposal options in western Massachusetts has been Maxymillian Technologies' ENCAP facility. Located primarily at Maxymillian's facility at 1801 East Street, Pittsfield, MA, the actual asphalt batching unit was transportable, allowing Maxymillian to bring it to project sites and move it around their facility. No data on how often it was used off-site is available at this time.

Maxymillian's ENCAP or "asphalt encapsulation" treatment method has been marketed as a disposal methodology that:

> "…employs asphalt emulsions to encapsulate, stabilize, and solidify petroleum-contaminated soil to produce an environmentally safe asphaltic material" (Maxymillian, date unknown)

According to their literature, Maxymillian first passes soil through size-reducing crusher system that provides a consistent aggregate. This is then fed into a mixing unit where is combined with an asphalt emulsion or liquid asphalt to produce the finished asphalt product. Their mobile facility can process material contaminated by #2 fuel oil (home heating oil), diesel, kerosene, jet fuel, #4 oil, and #6 oil.

Maxymillian is no longer accepting petroleum-impacted soil (PCS) as of June 2019 (Wood personal discussion, Feb 2020). According to Charles Riccardi of Maxymillian, they learned that MassDEP was making changes to the permitting process and determined that renewal of their permit and continued operations for this line of their business was not cost-effective. Maxymillian submitted a letter of voluntary surrender to MassDEP in June of 2019 and MassDEP responded in acceptance.

Mr. Riccardi acknowledged to the author (S. Wood personal discussion, Feb 2020) that the shuttering of their ENCAP operations places additional significant pressure on the already tight disposal sector. He recognized the limited number of available landfills to accept waste material, as well as the increased demand on Ondrick in Chicopee. Any other option for PCS disposal would be outside of Massachusetts (potentially west into New York or North into Vermont).

As previously stated, Maxymillian has historically been a disposal resource for the western part of Massachusetts, especially the area west of the Connecticut River. As of the 2018 MassDEP BWSC Active Landfill List previously discussed, only three landfills are located in MassDEP's Western Region that may have accepted material processed by Maxymillian: Specialty Materials – Notch Rd (Adams, MA), Bondis Landfill (Agawam, MA), and Chicopee Landfill (Chicopee, MA). It should be pointed out that, of these three, Specialty Materials was anticipated to reach capacity in 2019 and Chicopee Landfill in 2018; this makes the likelihood of these locations being a viable disposal location option moving forward questionable. It is reasonable, then to assume that materials from this region will be shipped to Ondrick in the future. A review of MassDEP BOLs for material transported to Maxymillian reveals the data documented in **Table Thirteen**.

Table Thirteen
Maxymillian Data

	2010	2011	2013	2018	2019
Total BOLs	12	473	793	832	777
Maxymillian BOLs	0	14	16	18	4
Maxymillian % of BOLs	0%	3%	2%	2%	1%
Maxymillian Ext. Miles	0	2,406.60	4,916.20	2,173.40	701.20
Metric T of CO_2	0	4.07	8.32	3.68	1.19
Annual Total Metric T CO_2	15.01	858.32	38,33.31	76,89.79	20,375.11
% of Annual Total Metric T	0%	0.47%	0.22%	0.05%	0.01%

As noted, none of the posted completed MassDEP BOLs in 2010 had Maxymillian as their destination. Similarly, Maxymillian surrendered their permit six months into 2019 so the total loads they received in that year is artificially small.

By means of comparison, an alternative scenario has been calculated to project what the GHG emissions would have been for the transport of these materials in Maxymillian's absence. Alternative totals have been calculated for these MassDEP BOLs with the destination location changed to be Ondrick. The results of this alternative scenario are provided below in **Table Fourteen**.

Table Fourteen
Alternative Scenario ~ Ondrick, Chicopee

	2010	2011	2013	2018	2019
Alt. Ext. Miles	-	7,514.00	22,595.20	11,503.40	1,933.60
Alt. Metric T of CO_2	-	12.72	38.26	19.48	3.27
Alt. Annual Total Metric T CO_2	-	866.97	3,863.24	7,705.59	20,377.20
% of Alt. Annual Total Metric T CO_2	-	1.47%	0.99%	0.25%	0.02%
Original Annual Total Metric T CO_2	*15.01*	*858.32*	*3833.31*	*7689.79*	*20375.11*
% Increase Alt. over Original	*0%*	*1.01%*	*0.78%*	*0.21%*	*0.01%*

This illustrates that the removal of a local or regional option results in a measurable increase in the GHG emissions from the transportation of the waste. The material is still being processed via asphalt batching, so facility emissions can assume to be equal or at least comparable to what they would have been if the same material was taken to a closer facility. Therefore, the transportation of these materials to another location is counterproductive to GHG emission reduction efforts.

Aggregate Industries

In 2011, Aggregate Industries operated three locations that accepted waste material for asphalt batching: Stoughton, Shrewsbury, and South Dennis. These facilities are still operating, but no longer accept contaminated material. The Stoughton location was both operational headquarters and the largest facility; it is in Southeast Region, proximate to the regional boundary with Northeast Region. The South Dennis facility is in Southeast Region, actually on Cape Cod itself. The Shrewsbury facility is in Central Region. Discussion regarding Aggregate Industries will be broken down by facility location, as well as the corporation overall influence.

Aggregate South Dennis

Of all Aggregate Industries' facilities, the one located in South Dennis was the least active for the purposes of this study. There were no finalized MassDEP BOLs submitted for South Dennis as a destination during 2010, 2018, or 2019. To reiterate, the 2010 data is abbreviated because of the institution of the online filing system so late in the year. As a policy, South Dennis was not accepting PCS in either 2018 or 2019. However, analysis shows that South Dennis played an important part in what could be called a niche disposal market on Cape Cod (in MassDEP's Southeast Region), similar to that Maxymillian has played in western Massachusetts. The ultimate removal of this facility and periodic closings prior to that during the period studied shows the real emission effects of lacking localized options as documented in **Table Fifteen**.

Table Fifteen
MassDEP BOLs to Ondrick

	2010	**2011**	**2013**	**2018**	**2019**
Total BOLs	12	473	793	832	777
South Dennis BOLs	0	9	14	0	0
South Dennis % of BOLs	0%	2%	2%	0%	0%
South Dennis Ext. Miles	-	1,588.80	3,947.60	-	-
Metric T of CO_2	-	2.69	6.68	-	-
Annual Total Metric T CO_2	15.01	858.32	3833.31	7689.79	20375.11
% of Annual Total Metric T	0%	0.3%	0.2%	0%	0%
Total Loads	*53*	*4972*	*21,093*	*24,501*	*40,538*
South Dennis Total Loads	*0*	*30*	*62*	*0*	*0*
% of Total Loads	0%	1%	0%	0%	0%

Apart from one MassDEP BOL for nine loads of material coming from Somerville (the same site also sent material to Aggregate's Stoughton facility), all generation locations were on Cape Cod or the Island of Martha's Vineyard.

Aggregate Shrewsbury

Aggregate Industries' Shrewsbury location is positioned in Central Region and within several minutes travel time to Interstates I-90, 1-395, I-290, and I-190; this easily accessible position made it an important resource to the region. Indeed, over the years reviewed, only five MassDEP BOL's were for wastes originating outside of Central Region; these were from the towns of Framingham and Ashland, both of which are proximate to the boundary between Central and Northeast Region. The data for Shrewsbury is presented in **Table Sixteen**.

Table Sixteen
MassDEP BOLs to Aggregate Industries Shrewsbury

	2010	2011	2013	2018	2019
Total BOLs	12	473	793	832	777
Shrewsbury Totals	0	22	7	26	2
Percentage of BOLs	0%	5%	1%	3%	0%
Shrewsbury Ext. Miles	-	7,166.60	663.60	1,602.60	188.60
Metric T of CO_2	-	12.13	1.12	2.71	0.32
Annual Total Metric T CO_2	15.01	858.32	3833.31	7689.79	20375.11
% of Annual Total Metric T	0%	1.4%	0.0%	0%	0%
Total Loads	*53*	*4972*	*21,093*	*24,501*	*40,538*
Shrewsbury Total Loads	*0*	*210*	*60*	*60*	*7*
% of Total Loads	0%	4%	0%	0%	0%

Aggregate Saugus

Aggregate Industries has operated a large quarry location in Saugus to produce raw materials for its various products. In June of 2017, Aggregate Industries announced that it would fill over 30 acres at the site with "Massachusetts Contingency Plan (MCP) and non-MCP disposal sites, out-of-state soils, dredged material and blasted rock. Per MassDEP requirements, any materials that arrive at the site must come from a known, tested source, with licensed site professionals overseeing both the generator's soil and operations at the reclamation project." (wickedlocal, 2017). According to Aggregate Industries' Fill Management Plan dated March 2017, this is being performed in one area of the quarry while operations continue in other sections (Aggregate Industries, 2017). This land reclamation project was/is subject to appropriate MassDEP permitting.

Of the finalized MassDEP BOLs reviewed, material being shipped to Saugus only first appeared in 2019. That BOL represented 248 loads of material removed from a single site in Peabody, MA, 7.1 miles from the quarry. This 3,521.6-mile effort resulted in the generation of less than 0.01 metric tons of CO_2, and consequently did not contribute to the CO_2 increase observed over the studied years in any measurable way. However, the beginning of this project does represent a potential alternative disposal option for Massachusetts-regulated materials and has the potential to reduce emissions that would be generated in its absence. If nothing else, the Saugus Quarry project has the potential to provide at least a partial offset to the transportation CO_2 increases created by the Aggregate Industries operational changes at the South Dennis, Shrewsbury, and Stoughton locations.

Aggregate Stoughton

Of the Aggregate Industries facilities, its asphalt batching plant in Stoughton, MA, was the most significant for the purposes of this study. The information gathered on the Stoughton location through the review of MassDEP BOLs for the years previously indicated is provided in **Table Seventeen**.

Table Seventeen
MassDEP BOLs to Aggregate Stoughton

	2011	2013	2018	2019
Total BOLs	72	113	38	3
Total Loads	365	525	196	10
Total Ext. Miles	363	27,040.4	8,587.4	358.00
Metric Tons of CO_2	0.62	45.83	14.55	0.61

Aggregate Industries Overall Effect

A significant decrease in Massachusetts destinations is attributable to the cessation of Aggregate Industries' facilities accepting impacted soil. The following **Table Eighteen** illustrates the role Aggregate played in the transportation emissions over the period.

Table Eighteen
Aggregate Industries Summary

	2010	2011	2013	2018	2019
Total BOLs	12	473	793	832	777
Total Loads	*53*	*4972*	*21,093*	*24,501*	*40,538*
Aggregate BOL Totals	0	102	133	63	6
Aggregate Total Loads	*0*	*719*	*1,121*	*256*	*265***
Percentage of BOLs	0%	22%	17%	8%	1%
Percentage of Total Loads	0%	14%	5%	1%	1%
Aggregate Ext. Miles	0	31,519.4	44,784.2	10,190	4,068.2
Metric Tons of CO_2	0	53.36989	75.83037	17.25411	6.888436
Annual Total Metric Tons CO_2	15.01	858.32	3,833.31	7,689.79	20,375.11
% of Annual Total Metric Tons	0%	6%	2%	0%	0%

MassDEP BOLs finalized in 2019 represent Aggregate-accepted loads at three sites: Stoughton, Shrewsbury, and its quarry in Saugus, MA. Note that Saugus is in the Northeast Region. It is important to point out, however, that Aggregate only accepted loads under six MassDEP BOLs finalized in 2019;

these constituted of 265 loads, 248 of which went to the Saugus quarry from a single site in Peabody (also in the Northeast Region). How then did the scale down of and cessation of Aggregate's acceptance of materials under MassDEP BOL affect other asphalt batching facilities?

A review of MassDEP BOLs for material taken to Ondrick Materials & Recycling, LLC (Ondrick) has been conducted to determine an answer to this question. Ondrick is in Chicopee, MA, which is solidly within the bounds of Western region. RTNs were searched for each year by numerical indicator and the following results were generated.

Table Nineteen
Regional MassDEP BOLs to Ondrick

	2010	2011	2013	2018	2019
Western	0	57	72	55	39
Central	2	6	15	25	43
Northeast	0	3	2	16	18
Southeast	0	1	1	10	18
Totals	***2***	***67***	***90***	***106***	***118***

As noted, there has been a dramatic increase in materials being shipped to Ondrick from sites in the Northeast and Southeast Regions. In 2013, only four loads were transported to Ondrick from Northeast and Southeast Regions combined. In 2018, 149 loads were shipped from the Southeast Region and 109 loads from Northeast Region; in 2019, 151 loads were shipped from Southeast Region and 95 loads from Northeast Region. Even if the Aggregate South Dennis facility was shuttered at the time, these loads would have been shipped to Aggregate Stoughton.

As an alternative to how these loads were actually managed (i.e. shipment to Ondrick), the miles from the generation address to Aggregate Stoughton were calculated. The results for these 2018 and 2019 loads compared with the actual results (to Ondrick) are documented below in **Table Twenty**.

Table Twenty
Aggregate Alternate Scenario

		# Loads	Actual Ext.Miles	Alternative Ext.Miles	Difference	CO_2 Metric Tons
2018	Northeast	109	16,963.20	5,171.60	11,791.60	19.97
	Southeast	149	30,100.60	7,581.40	22,519.20	38.13
2019	Northeast	95	15,591.80	4,334.80	11,257.00	19.06
	Southeast	151	33,450.60	8,749.60	24,701.00	41.82
					Total	***118.98***

As documented, the closure of the Aggregate Stoughton facility can be said to have generated a total of 70,268.80 excess miles due to transport to Ondrick from sites in the Northeast and Southeast Regions.

This equates to the generation of 118.98 metric tons of CO_2 through vehicle emissions during transport that could have been avoided if either Aggregate Stoughton had accepted the material or another option was available in the same area.

Brox Discussion

Brox Industries is yet another asphalt batching company that has traditionally accepted contaminated material for use in the asphalt process. Brox has not played a major role in the years reviewed by this study but has maintained a presence. They historically (as seen through the review of the MassDEP BOLs during this study and personal discussions) operated two locations that accepted PCS: one in Dracut, MA, and one in Marlborough, MA. Only the Dracut facility continues to accept PCS under MassDEP BOL. The Marlborough activity was not significant enough to warrant separate review, so both locations will be discussed as a single unit. However, the miles from a generation address to the designated facility reflect whether the material went to Dracut or Marlborough. Brox study information is provided below in **Table Twenty-One**.

Table Twenty-One
MassDEP BOLs to Brox Industries

	2011	2013	2018	2019
Brox Total BOLs	19	10	5	14
Percentage of MassDEP BOLs	4%	1%	1%	2%
Brox Ext. Miles	7,077.20	3,015.20	1,740.60	3,515.80
Metric Tons of CO_2	11.98	5.11	2.95	5.95
Annual Total Metric Tons CO_2	858.32	3833.31	7689.79	20375.11
% of Annual Total Metric Tons	1.40%	0.13%	0.04%	0.03%
Brox Total Loads	160	54	35	71
% of MassDEP BOL Total Loads	3.2%	0.3%	0.1%	0.2%

In discussion with Daniel Tencza of Brox Industries, the author was told that under the current climate there is no financial incentive to increase their intake of PCS in Dracut or begin taking PCS in again in Marlborough (S. Wood personal discussion, 2019). Additional spatial and segregation from non-PCS materials requirements have gone into effect since the 2000s that make it significantly more costly to handle PCS for asphalt batching. Additionally, Mr. Tencza informed the author that MassDOT's new "Superpave" engineering specifications for asphalt (effective 2018) on MassDOT-controlled roadway do not allow for the use of PCS as raw material, further lessening the potential market for asphalt generated using PCS (S. Wood personal discussion, February 2020).

Brox continues to play a small role in the disposal of MassDEP BOL-managed wastes. There is little to no probability that Brox will expand this operation and an actual greater likelihood the company with abandon it as Maxymillian did. With regard to CO_2 generated by taking MassDEP BOL wastes to Brox, it is too minimal to present a significant diversion if Brox stopped accepting these wastes.

Reclamation Projects – In State

Massachusetts has recognized the potential benefits of reclaiming large tracts of land that was previously fully used as pits and quarries. MassDEP has issued guidance (interim) on the suitability of such projects and developed a process of issuing Administrative Consent Orders (ACOs) to approve them. These are only projects that will use over 100,000 cubic yards of material (MassDEP via Mass.gov, nd).

The following list presents reclamation projects approved as of October 30, 2018:

- Marilyn's Landing, Bridgewater, MA (RTN 4-26987)
- Route 44 Development Project, Carver, MA (4-26986)
- Dudley Reclamation Project, Dudley, MA (RTN 2-19820)
- Sewell Street Reclamation Project, Groveland, MA (RTN 3-35151)
- O'Donnell Sand/Gravel Pit, Kingston, MA (RTN 4-26367)
- Jordan Overlook Farm, Rutland, MA (RTN 2-19106)
- Aggregate Industries, Saugus, MA (RTN 3-34330)
  (MassDEP via Mass.gov, nd)

The Aggregate Saugus project was previously discussed in the Aggregate Industries section of this study.

The reclamation projects policy is relatively new and (as previously stated in relation to Aggregate Saugus) has the potential to reduce CO_2 emissions by providing localized disposal options. As can be seen through the regional numeric identifier portion of the RTNs, three of the approved locations are in the Southeast Region, two in the Northeast Region, and two in the Central Region.

Few MassDEP BOLs reviewed in this study represented materials taken to these locations; however, those that did show promise that these locations will be significant to the industry in reducing CO_2 emissions. They are summarized in **Table Twenty-Two**.

Table Twenty-Two
MassBOLs for Reclamation Projects

	2018	2019
# Projects Involved	1 (Marilyn's Landing)	3 (Marilyn's Landing, Aggregate Saugus, Route 44 Development)
# BOLs	2	5
# Loads	146	760
Total Ext. Miles	8,847.6	49,036.00
Total Metric T CO_2	14.99	83.10

The total metric tons of CO_2 represent a minimization of the GHG emissions that could have been generated if this material was taken elsewhere, likely into New Hampshire or Maine. In that, this a tremendous reduction and is a positive step forward in in-state GHG transportation emissions control.

As with many situations, soil reclamation projects have a maximum life span, either due to capacity or controversy. The following three projects were permitted but are no longer accepting soil:

- St. Mary's Cemetery, Tewksbury, MA
- Green Acres, Uxbridge, MA
- 540 Groton Materials, Westford, MA

Multiple problems and public outcry were significant factors in the Green Acres reclamation project (Spencer, 2019). The same was true of the 540 Groton Materials project in Westford (Silva, 2017). There have been operational issues associated with the active Dudley reclamation project (Spencer, 2016) and the Jordan Overlook Farm (MassDEP, 2018); additionally, the Jordan Overlook Farm project was the subject of criticism from its inception (Owen, 2016) but will likely be approaching capacity soon (S. Wood personal discussions, 2020). These projects are subject to the same stigma issues that will be discussed later regarding landfill siting.

Out-of-State Transportation

As has been shown, the number of viable disposal options within Massachusetts has been reduced. This has resulted in the shipment of greater volumes of material (specifically solids) out of state. None of the 2010 MassDEP BOLs were for the management of material transported out of state, so only 2011, 2013, 2018, and 2019 will be discussed.

The overall results of this trend as seen through the MassDEP BOL review are documented below, as well as the CO_2 emissions generated through the transport to these out-of-state destinations. These results are summarized in **Table Twenty-Three**.

Table Twenty-Three
Out-of-State Overview

	2010	2011	2013	2018	2019
Total Out of State BOLs	7	167	359	421	435
% of Annual BOLs	58%	*35%*	*45%*	*51%*	*56%*
Out of State Loads	23	1,543	9,741	13,645	21,393
Out of State Ext. Miles	7077.4	295,545.4	1,554,037.4	3,754,320.6	10,315,738.6
Class 8 MPG diesel	5.9	5.9	5.9	5.9	5.9
Gal diesel consumed	1199.6	50,092.4	263,396.2	636,325.5	1,748,430.3
lbs CO_2/gal	22.0242	22.0242	22.0242	22.0242	22.0242
Total LBS CO_2	26,420.23	1,103,245.93	5,801,089.92	14,014,560.64	38,507,777.98
Total Metric T CO_2	**15.01**	**500.87**	**2,633.69**	**6,362.61**	**17,482.53**
% Annual CO_2 Increase	N/A	N/A	426%	142%	175%

As shown, the percentage of MassDEP BOLs reflecting out of state transport has consistently increased and constituted more than half of the BOLs finalized in both 2019 and 2019. In the light of previous discussions on Massachusetts in-house disposal capabilities, this trend is unlikely to shift on its own.

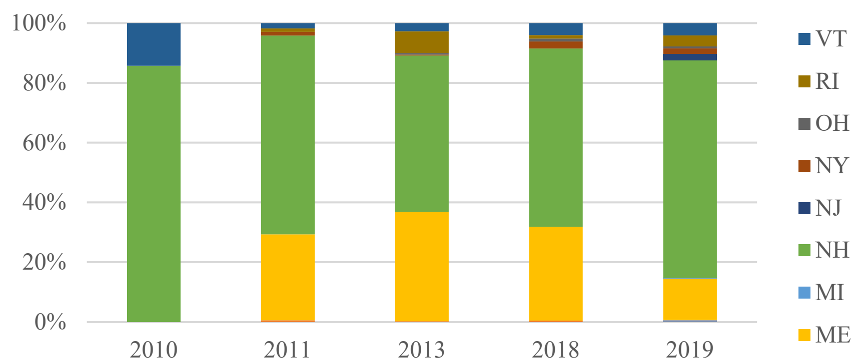
More significant, however, is the increase in the distances these loads are traveling (as documented by Ext. Miles) and tremendous increase in CO_2 emissions as a result. Out of state transportation for disposal accounted for 58% of CO_2 emissions in 2011, 69% in 2013, 83% in 2018, and 86% in 2019. Between 2018 and 2019, there was a 175% increase in Ext. Miles, even though the total number of MassDEP BOLs reflecting out of state transport were relatively close in number (421 versus 435). The fact that there was such an increase in the number of loads (by 7,748) does indicate that several projects were underway that generated a significant amount of material. However, the average distance more than doubled from 2018 to 2019; this indicates that the lack of available facilities in state is exerting significant pressure and loads are moving from further away.

This begs the question of where these loads are being transported to as well as where they are coming from. The data on this is provided in **Table Twenty-Four** and visually depicted on **Figure 4**.

Table Twenty-Four
MassDEP BOL Out-of-State Destination Locations
By Year

	2010	2011	2013	2018	2019
Blank	0	0	0	0	1
CT	0	1	1	2	0
GA	0	0	0	0	2
ME	0	48	131	132	60
MI	0	0	0	0	1
NH	6	111	188	251	317
NJ	0	0	0	0	9
NY	0	2	1	10	8
OH	0	0	2	4	3
RI	0	2	26	5	16
VT	1	3	10	17	18
Total	***7***	***167***	***359***	***421***	***435***

Figure 4
Out-of-State Composition



As documented in **Table Twenty-Four** and depicted on **Figure 4**, the majority of the out of state shipments have been to Maine and New Hampshire. Indeed, the number of MassDEP BOLs for shipment to New Hampshire has far outweighed material traveling anywhere else and has comprised 63% of all the out of state BOLs reviewed in this study.

There are points about this data that require clarification. These are discussed below.

- The 2019 "blank" BOL was a pdf uploaded with absolutely no information on it; a cursory review of the associated report documents online seem to indicate that it was for material shipped to New Hampshire, but this could not be confirmed; the generated statistics include the existence of this BOL, assume that it is for out of state transport, but there are no mileage or emission calculations associated with it.

- MassDEP BOLs for shipments to Georgia, Ohio, and Michigan were observed during this study. Without a thorough review of the report documents associated with them, it is unclear why these loads were taken so far away. However, it does happen that during the waste characterization process levels of contaminants of concern [COCs (oftentimes metals)] are observed at levels that are not allowed by more proximate facilities; this was briefly discussed regarding the physical and chemical characterization requirements. It is assumed, but not confirmed, that this is the reason for these outliers. Regardless, the miles associated with these BOLs and associated emissions are included in the study dataset but are not believed to be part of any distinct observed trends.
- The single MassDEP BOL for Connecticut in 2013 represented waste that was moved to Connecticut for temporary storage prior to being shipped to Ondrick for disposal. Scenarios such as this happen when waste is generated through roadside emergency response actions and must be moved for public safety considerations or there is not enough space on a property to store waste during the characterization process. MassDEP BOLs for Connecticut in 2011 and 2018 do represent material that was shipped directly for disposal in Connecticut [Phoenix Soils (Waterbury, CT) in 2011 and Clean Earth (Plainville, CT) in 2018].

The definitive trend has been identified to move material to Maine and New Hampshire as the out of state option for disposal. This raises the question of where in these states the material is going and how much CO_2 is being generated in getting there.

The following **Table Twenty-Five** lists out what the disposal location in each case by year was.

Table Twenty-Five
MassDEP BOL Maine & New Hampshire Disposal Locations

	2010	2011	2013	2018	2019
ME	N/A	ARC, Eliot, ME	ARC, Eliot, ME	ARC, Eliot, ME	ARC, Eliot, ME
		CP&R, Scarborough, ME	Clean Harbors, S. Portland, ME	Clean Harbors, S. Portland, ME	Clean Harbors, S. Portland, ME
		MER, Biddeford, ME	CP&R, Scarborough, ME	CP&R, Scarborough, ME	CP&R, Scarborough, ME
				Crossroads Landfill, Norridgewock, ME	Crossroads Landfill, Norridgewock, ME
NH	ESMI, Loudon, NH	ESMI, Loudon, NH	ESMI, Loudon, NH	NCES Landfill, Bethlehem, NH	NCES Landfill, Bethlehem, NH
		Four Hills Landfill, Nashua, NH	Haverhill Landfill, Haverhill, NH	ESMI, Loudon, NH	ESMI, Loudon, NH
		Portsmouth Landfill, Portsmouth, NH	Turnkey Landfill, Rochester, NH	Four Hills Landfill, Nashua, NH	Four Hills Landfill, Nashua, NH
		Turnkey Landfill, Rochester, NH		Tradebe, Newington, NH	Tradebe, Newington, NH
				Goulet Trucking * Northfield, NH	Turnkey Landfill, Rochester, NH
				Turnkey Landfill, Rochester, NH	

ARC = Aggregate Recycling Corp. MER = Maine Energy Recovery CP&R = Commercial Paving & Recycling Corp., NCES = North Country Environmental Services
*Goulet Trucking was a temporary storage location; the waste ultimately went to ESMI for disposal

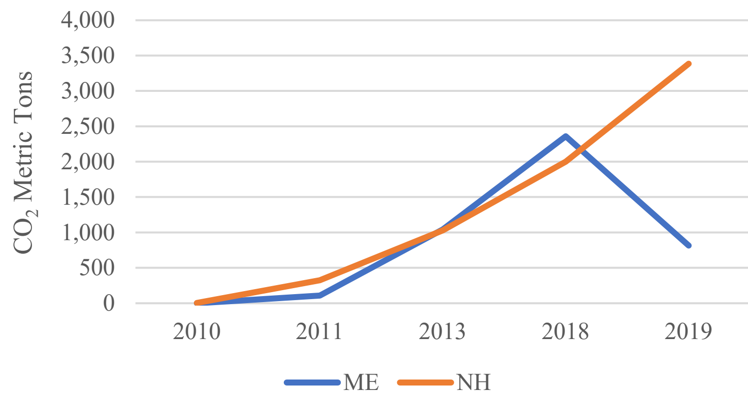
As documented in **Table Twenty-Five**, the number of disposal locations remain relatively stable over the years reviewed. There is no significant increase in the number of locations or turn-over where multiple facilities are opening and quickly closing. What then, are the CO_2-generation implications of increased shipments to these locations based on the MassDEP BOLs reviewed?

Table Twenty-Six
Maine & New Hampshire Studied Emissions

		2010	2011	2013	2018	2019
ME	ME BOLs	N/A	48	131	132	60
	Total Loads		321	3,625	4,696	1,819
	Total Ext. Miles		63,968.00	615,668.00	1,393,234.00	480,236.60
	Total Metric T CO_2		108.41	1,043.40	2,361.17	813.88
NH	NH BOLs	6	111	188	251	317
	Total Loads	12	1,129	3,892	7,438	12,682
	Total Ext. Miles	2,215.40	190,785.60	607,662.60	1,180,700.60	1,997,827.20
	Total Metric T CO_2	3.75	323.33	1,029.83	2,000.98	3,385.80

Figure 5 below shows the progression of the total metric tons of CO_2 generated through the transport of materials to New Hampshire versus Maine.

Figure 5
Total Metric Tons CO_2



Maine

Regarding Maine, from 2013 through 2019 the average number of loads per MassDEP BOL ranged between 27 and 36. Even with the substantial decrease in finalized BOLs in 2019, the average number of loads was 30. However, even with the decrease in number of BOLs and total loads in 2019, the average number of miles expressed as Ext. Miles remains high: 264 miles in 2019 over 1,819 loads compared to 296 miles in 2018 over 4,696 loads.

Table Twenty-Seven
ME MassDEP BOLs by Region

	2010	2011	2013	2018	2019	% of Total
Western	0	2	5	2	0	2%
Central	0	1	14	2	2	5%
Northeast	0	42	107	118	52	86%
Southeast	0	3	5	10	6	6%
Total	*0*	*48*	*131*	*132*	*60*	*371*

Even with the drop in total number of MassDEP BOLs for Maine destinations in 2019, the six from Southeast Region that year comprised 10% of the BOLs; the calculated 364,231.80 Ext. Miles traveled under those MassDEP BOLs represented the generation of 617.28 metric tons of CO_2, 76% of the calculated total CO_2 for that year. Given the continuing lack of viable disposal options in the eastern Massachusetts (Northeast and Southeast Regions) and anticipated further reduction in in-state disposal options, reliance on the Maine sector is anticipated to remain constant or increase; this will further exacerbate CO_2 emissions.

New Hampshire

As documented in **Table Twenty-Six**, the number of miles (as expressed as Ext. Miles) related to transport of wastes to NH has increased dramatically over time, as has the resultant CO_2 emissions. Since 2011, only one permanent additional facility has come online; to reiterate, the Northfield location was a single-time temporary storage situation. Closer review of New Hampshire is certainly warranted in this study. **Table Twenty-Eight** shows the breakdown of finalized MassDEP BOLs with New Hampshire destinations during the study years. **Table Twenty-Nine** shows the CO_2 generation associated with these years and is depicted in **Figure 6**.

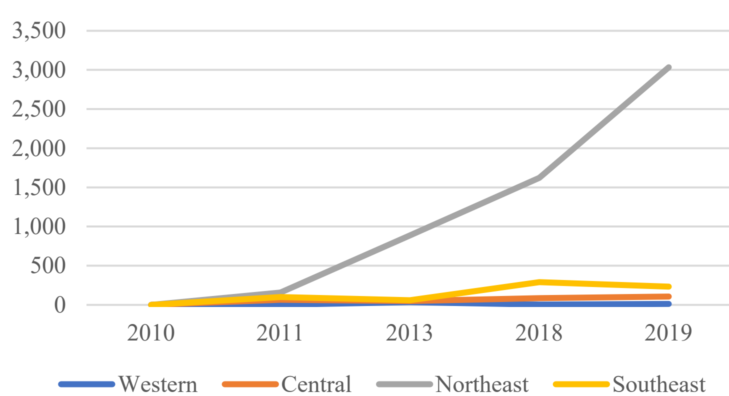
Table Twenty-Eight
NH MassDEP BOLs by Region

	2010	2011	2013	2018	2019
Western	1	1	8	4	4
Central	0	19	20	25	30
Northeast	3	76	141	171	218
Southeast	2	15	19	51	65

Table Twenty-Nine
NH Mass BOL Region Metric T CO_2

	2010	2011	2013	2018	2019
Western	0.43	1.91	35.21	3.29	12.59
Central	0.00	64.36	49.33	85.69	107.20
Northeast	3.75	156.82	886.14	1621.91	3033.63
Southeast	1.62	100.24	59.15	290.10	232.39

Figure 6
Metric Tons of CO_2 by Region



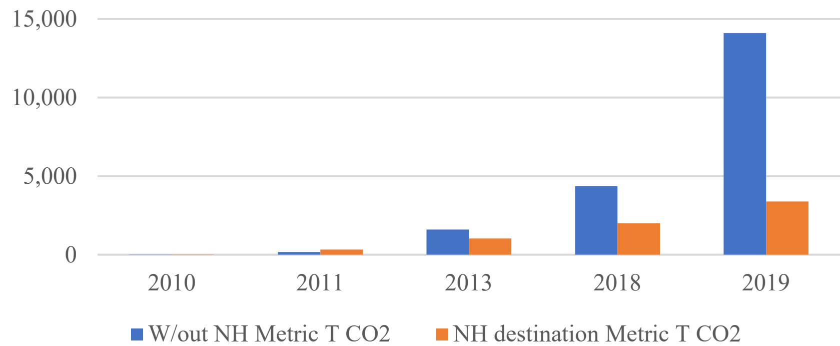
New Hampshire related transportation emissions are such an outlier that they deserve consideration on their own. The following **Table Thirty** and **Figure 7** show the total levels of CO_2 emissions minus New

Hampshire represented by the years of MassDEP BOLs reviewed compared to New Hampshire and depicts this accordingly.

Table Thirty
Metric Tons CO_2 compared with NH CO_2 Emissions

	2010	2011	2013	2018	2019
W/out NH Metric T CO_2	11.26	177.54	1,603.86	4,361.62	14,096.72
NH destination Metric T CO_2	3.75	323.33	1,029.83	2,000.99	3,385.81

Figure 7
NH Comparison



As documented above, until 2019, loads taken to New Hampshire statistically represented over one-third of the GHG vehicle emissions generated. This dropped substantially in 2019 to represent only 19.37 %, which is still a substantial component. However, as previously discussed, the 2019 data is skewed by outlier transports to Georgia, Michigan, and Ohio. Further discussion follows.

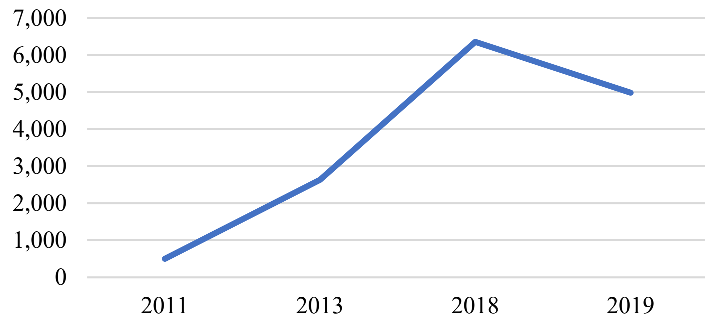
Encore Boston Harbor Casino

The material shipped to Georgia, Michigan, and Ohio in 2019 was handled under six MassDEP BOLs. These BOLs accounted for 4,763 loads in total and 12,496.74 metric tons of CO_2 emissions. 4,745 of these loads were attributable to the Wynn Resorts build-out of the Encore Boston Harbor Casino in Everett, MA. This was a well-publicized brownfield redevelopment project. 4,469 loads were transported from the project site to Sunny Farms Landfill in Fostoria, OH. The MassDEP BOLs indicate that 276 loads were transported to Taylor County Landfill in Mauk, GA. In total, the calculated Ext. Miles for these shipments were 7,373,824 miles and the generation of 12,451.79 metric tons of CO_2. This could be considered a "one time" occurrence sine it was a known brownfield redevelopment location and the project is complete. However, these loads represented 61% in 2019 of the CO_2 generated based on the findings of this study. With the removal of this outlier, the trend of exponential increased travel out of state continues based on the data (reduction from 2018 but close to doubling 2013 levels), but on a more measured and expected path. This is shown in **Table Thirty-One** and depicted on **Figure 8**.

Table Thirty-One
Corrected 2019 Metric Tons CO_2

	2011	2013	2018	2019
Corrected Metric T	500.87	2,633.69	6,362.61	4,985.79

Figure 8
Corrected Out-of-State CO_2



It must be noted that the Encore Boston Harbor casino also generated material that was taken to in-state locations. That said, although this project considered an outlier, it is probable that situations such as this will continue to develop in the future. Indeed, as developmental density increases and brownfield site reuse becomes more common, the probability increases accordingly. What is in question is the ways in which these sites can be handled to reduce CO_2 emissions from waste transport during the redevelopment process.

Additional Information Regarding Asphalt Batching

In subsequent discussion with Ondrick personnel (S. Wood personal discussions, Feb. 2020), further information about the status of asphalt batching came to light. According to Jacob Haley of Ondrick, PCS is primarily used in the production of "cold batch" asphalt rather than "hot batch". Although it might not be specifically prohibited by MassDOT's Superpave specifications, the materials come from many different sources; this has been readily obvious through this study's analysis of where materials taken to asphalt batching facilities are originating from. According to Mr. Haley, depending on areas' soil types, the resulting mix has a heterogeneity that does not allow for a constant consensus in the mix; this does not allow for consistency that assures meeting the volumetric properties of the Superpave requirements (S. Wood personal discussions, Feb. 2020).

When the author asked Mr. Haley where the resulting cold batch mix was being used if not for general paving projects, he responded that Ondrick is primarily sending it to landfills to be used as cover. The closure of landfills over time is consequently constricting the market for this recycled material, as well.

According to Mr. Haley, several years ago, Ondrick was providing cold batch asphalt as cover to multiple landfills (as many as eight, he said, but he did not specify which ones). At this point, Mr. Haley told the author that the landfill numbers that were accepting Ondrick's cold batch asphalt as cover had dropped to three or four (S. Wood personal discussions, 2020).

This study has already explored what the elimination of multiple asphalt batching facilities has caused in GHG emissions increases. In light of what this study has shown about the past, continued, and expected future contraction of the landfill market as a disposal location option, this information is especially concerning. With additional landfill closures expected and the further pressure these closures will exert on asphalt batching, it is not beyond the realm of foreseeable possibility that all the solid materials generated will have to be transported out of Massachusetts for disposal. The GHG emissions increase from this would be enormous based on the overall trends observed in this study.

Recommendations

Additional Usage of Soils/Sediments in Asphalt Batching

The Massachusetts Aggregate and Asphalt Pavement Association (MAAPA) is comprised of seventeen regular company members (MAAPA, nd). In discussion with several MAAPA member companies, the author confirmed that, of these, only Ondrick and Brox are currently accepting PCS for reuse in asphalt batching. (S. Wood personal discussions, 2020). As previously stated, according to Mr. Tencza of Brox, MassDOT's current Superpave specifications do not allow for the use of (or contraindicates the use of) PCS, which further reduces the financial incentive to take and process PCS. As referenced in the discussion with Mr. Haley of Ondrick, the commercial market viability for cold batch products has shrunk to largely landfills and these landfill options are shrinking. Considering this information, MassDEP, MassDOT, the Massachusetts regulated community as represented by the License Site Professional Association (LSPA) and the leadership of MAAPA should work together to find alternative options for the use of PCS-based asphalt products.

Landfill Development

It can be fairly assumed that a significant amount of stigma is associated with the siting and development of landfill properties/land within communities. However, education of the public about innovative technologies as well as engineering controls that have been developed since the traditional concept of the "town dump" is instrumental in reducing these issues and making the concept of local landfills potentially more palatable.

A prime example of this situation is the current debate raging in Lee, MA, over the creation of a new landfill to be designated as the "Upland Disposal Facility", that would accept low-level Polychlorinated biphenyl (PCB) impacted soils associated with the remediation of the nearby Housatonic River (Dobrowolski & Berkshire Eagle, 2020).

This facility, according to EPA cited in the article, would accept low-level impacted material. Higher concentration amounts would be shipped out-of-state to Texas or Michigan. In the context of this study, the decision to do so is not questioned. However, the vehicular emissions associated with transporting material such distances are tremendous, so any potential reduction in the amount in transit (if allowable by state and federal guidelines) is beneficial. The primary hindrances are local ordinance and possibly the public perceptions of stigma. Clear and direct dialogue with local stakeholders and officials during the planning and permitting process about GHG emissions associated with "long distance" waste transport might serve to mitigate this obstacle.

As an alternative, the reactivation of landfills not yet capped is an option. According to MassDEP's "Inactive & Closed Landfills & Dumping Grounds" list published February 2018 (MassDEP, 2018), Clinton Landfill is listed as inactive and incomplete as of 1995. However, as has been demonstrated, Clinton Landfill has been very much active during the years reviewed in this study. The reason Clinton Landfill began to again accept material is that there was a plan developed in 2012 to recap the landfill after it was deemed non-compliant in its inactive status; this plan was anticipated to take eight years, during which time it would accept contaminated soil (Peto, 2012). According to discussions with Worcester, MA DPW personnel, Clinton Landfill is reaching the point at which it will be again capped and closed shortly (S. Wood personal discussions, 2019-2020). Note that this timeline is on target with the anticipated eight-year schedule.

With the anticipated re-capping of Clinton Landfill and the looming closure of Taunton Landfill (Winokoor, 2019), the potential to reactive inactive landfills that are not yet capped should be thoroughly investigated.

Thermal Desorption

Clean Earth in Plainville, CT, Clean Earth in Fort Edward, NY; and ESMI/Clean Earth in Loudon, NH, are thermal desorption facilities (Clean Earth/United RETEK of CT, 2019). Desorption is a process by which soils are heated to temperatures approaching 1,000ºF to volatilize COCs; after passing through a "bag house" for particulate removal, the gas stream is heated to approximately 1,600ºF, destroying the volatilized COCs (Clean Earth/United RETEK of CT, 2019). According to Mr. Todd Mahler of Clean Earth, the resulting GHG emissions from the process are less than those of a passenger vehicle.

In addition to Clean Earth's fixed facilities, they also have a mobile treatment unit (located out of the Plainville location) that has successfully been used to remediate a variety of sites including (but not limited to) a Hexavalent Chromium-contaminated site in New Britain, CT, in 2018 (S. Wood personal discussions, 2019; Clean Earth/United RETEK of CT, 2019).

Given the amount of contaminated material that can be generated in Massachusetts in a single year, it would be beneficial to open discussions with Clean Earth about siting a facility in a centralized location that would benefit both Northeast and Southeast Regions, potentially close to the Aggregate Industries Stoughton location. Barring that, large projects such as the Everett Boston Harbor Casino project should be encouraged to thoroughly investigate mobile thermal desorption as an alternative to transporting generated wastes elsewhere.

Discussion & Conclusion

This study has shown that the CO_2 emissions relative to the transport of wastes managed under MassDEP BOL have increased significantly over time. This trend has primarily been due to the reduction in the number of available disposal options. Contraction in the disposal industry has resulted in a substantial increase in miles required to arrive at an appropriate facility, be it asphalt batching, landfill, or otherwise.

In this situation, the resulting emissions are beyond the fault of the vehicle. Identified regulated wastes that must be disposed of under state and/or federal regulations need to be managed and disposed of appropriately. Unless these materials are treated in situ, they must be moved. The issue is where they are moved to.

If the Commonwealth of Massachusetts is truly committed to moving toward carbon neutrality while addressing other environmental concerns, attention must be paid to capturing and reducing GHG emissions as efforts are made to remediate sites. Excess CO_2 generation for materials in transport should not be the trade-off for improving the quality of land and water; otherwise, it renders environmental protection simply a shell game.

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