Improving Organic Materials Management in Washington State

An Assessment of the Barriers and Needs of Organic Waste Management Facilities in Washington State

Zero Waste Washington

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Executive Summary

While the organic waste management system in Washington State is one of the best in the nation, there is room for improvement – especially considering climate change. According to the Washington State Department of Ecology's most recent waste characterization report, 28.5% of the disposed load (landfill and incineration) in the state is organic material, by weight (Ecology, 2018a).

This project examined the current status of organic waste management in Washington, assessing barriers and needs for expanding and improving the system through data assessment, literature review, and interviews with 61 industry leaders and experts from the composting, anaerobic digestion, consulting, and government sectors. The report includes a set of recommendations for consideration by state and local policy and decisionmakers in further reducing the amount of landfilled organic waste in Washington. All findings and recommendations are based on research.

Findings

Existing capacity, markets, opportunities, and barriers to increasing and improving Washington's organic waste management system are summarized below.

Existing Capacity and Markets

Composting: Washington has 58 permitted composting facilities, located in 28 out of 39 counties, which processed 1.28 million tons of organic waste annually, with the largest volumes of feedstock processed in western Washington (2018 data). The most prevalent composting methods are aerated static pile and turned windrow, with the latter most used in eastern Washington. Mixed yard debris and food waste is mostly collected as feedstock in western counties, while manure and green waste (yard debris and agricultural organics) was widely collected in rural areas. Composting facilities' supply is mostly local, with the largest inter-county flow of materials observed between King and Snohomish, Spokane and Lincoln, and Clark, Klickitat, and Portland Metro (OR) counties.

Anaerobic digesters: Washington has a total of 43 anaerobic digesters producing biogas from organic materials, most of them (33) related to wastewater treatment facilities and nine farm-based. Volumes of organic material anaerobically digested in Washington increased during the period 2009-2012 and have varied between 30,510 and 44,467 tons a year through 2017, according to Ecology. All farm-based anaerobic digesters are in dairy-intensive areas (Skagit, Whatcom, and Yakima counties) and began operations in 2012 or earlier.

Vermiculture and Black Soldier Flies: Five units in the Monroe Correctional Complex run facilities use vermicompost, bokashi, and black soldier fly methods as part of their waste management and inmate employment programs, representing the best-known applications of these methods in the state. The system started in 2009 and aims to process most of the facilities' food waste (totaling 60 tons), currently processing nearly 15 tons of food waste a month. Worms are also being used to treat over 500,000 gallons per day of wastewater from dairy and winery operations in two facilities located in eastern Washington.

Land application sites: There are 15 land application sites holding a solid waste permit in Washington, regulated under WAC 173-350-230, mostly located in central and southern counties (especially Benton and Grant). Land application of organic waste such as food processing and agricultural organic material ranged between 6,241 and 11,112 tons between 2008 and 2017. These figures do not include land application in agricultural operations which do not require solid waste permits and include application of materials such as manure, bedding, crop residue, on-farm vegetative materials, compost, vermicompost, and digestate.

Incineration and energy recovery: Between 2006 and 2017, on-site energy recovery facilities processed between 334 and 876 thousand tons of organic materials per year (wood waste, land clearing debris, and yard debris). These facilities are permit-exempt under WAC 173-350-240 because they only process wood waste, wood-derived fuel, or wastewater treatment sludge generated from wood pulp and paper manufacturing. Several small capacity facilities operate in the state, producing biochar and other biofuels (under 12 tons per day).

Two energy recovery facilities are permitted to burn solid waste in Washington: Spokane Regional Waste-To-Energy and BioFuels Washington Energy. Incineration is considered a solid waste disposal method.

Landfill sites: Washington has 14 landfills in operation, which received 4.03 million tons of municipal solid waste during 2017. This total includes both organic and inorganic waste.

Barriers to capacity expansion of organic waste management facilities in Washington

Logistical challenges include cost of transportation, physical space needs for siting or expanding facilities, unclear zoning, responses to community concerns, and apple maggot quarantine restrictions.

Financial burden and risks impact business models that depend on external factors. Organic waste processing methods that recover value from wastes (e.g., anaerobic digesters) rely on government incentives, struggle from competition with landfills charging low tipping fees, compete with low prices of natural gas and renewables, and lack sufficient financial incentives. Anaerobic digester operators also struggle with developing back-end co-products without expensive treatment and lack of long-term contracts and markets for those co-products and associated feedstock.

Regulatory challenges include variability in application and interpretation of state regulations across counties, reflecting overburdened staff, uncertain criteria, and lack of needed data. There is also a lack of reliable and representative methods for measuring and estimating odors, volatile organic compounds, and other emissions related to organics management facilities (composting, anaerobic digestion, and biochar facilities), reflective of Washington State conditions. Variability in air quality permitting requirements and fees between Ecology, regional, and local agencies is also challenging, often not having a consistent structure or verbiage.

Operational issues include seasonal variation of feedstock types and quantities, nutrient loads of certain organic materials like food waste to composting operations (low-quality products and nuisance odors), high maintenance costs (anaerobic digesters), and lack of state definitions for renewable natural gas production.

Physical contamination from municipal sources, especially plastic and glass, lowers product quality and adds to pre- and post-processing operational costs. The issues are exacerbated by products that confuse consumers (compostable plastic-like products), wrap and clog equipment (compostable and non-compostable plastic bags), cause safety concerns (glass), and pose hazards related to toxic chemicals (PFAS in foodware products).

Chemical contamination associated with persistent herbicides continues to create a hazard and requires expensive testing.

Moderate to weak demand for end products results from highly competitive prices of standardized chemical soil amendments and fertilizers. It also results from low interest from farmers and other users who are not convinced of the benefits of organic waste management products (e.g., compost, biochar). Lack of spreading equipment and gaps in information about the benefits of products and how to apply them impose additional barriers to their adoption, accompanied by concerns about low product quality. In addition, there is confusion about the application of public procurement standards used by public agencies.

Knowledge gaps are found with the industry not universally adopting best management practices (also referred to as good management practices in some documents), local governments hampered by limited budgets and staff to regulate the industry, and a need to connect industry needs with new research and innovation.

Competition and coordination issues manifest in a lack of understanding of the differences and applications among different government and institutional compost public procurement standards. There is also a disconnect between traditional uses and benefits of compost compared to its increasingly relevant use for carbon sequestration. There is a need to conduct policy discussions that fully engage all stakeholders around climate and waste reduction goals.

Opportunities

Innovation and technology advancements of new applications for on-site composting and anaerobic digestion alternatives. Grinding food waste and creating a slurry for co-digestion at existing anaerobic digesters could improve commercial food waste collection efficiency and leverage existing capacities. The development and improvement of new technologies such as de-packagers could help address contamination problems thus, increasing the ability to process food waste that was previously inaccessible. Additional "up the pipe" improvements, such as surveillance technology in hauling companies, would further reduce contamination in the organic waste management system.

Grants and government support could benefit the industry, including incentivizing organic management as part of broader climate change strategies and waste reduction goals and creating financial stimulus for siting and upgrading facilities. Improved consumer education would contribute to cleaner feedstock.

Potential increased demand due to expanding the use of processed organics in certified organic and high-value crop markets, increasing use of government public procurement standards, enhanced consumer education and awareness initiatives, and increased renewable natural gas promoted via Washington's Clean Energy Transformation Act.

Legislative action in other states provides models that combine reduction targets with financial support and disposal limits, while incorporating safeguards to prevent increased contamination in feedstocks, and supporting broader policies addressing climate change, particularly those currently being discussed in the Western United States.

Recommendations

Below is a list of 37 recommendations identified through the literature and interviews with organic waste experts. These recommendations address industry barriers and opportunities to create systemic changes that foster organic material management and are organized into eight themes. These recommendations are meant to be actions that legislators, agencies, and others can incorporate into their strategies and goals. Further detail can be found starting page 74.

1. Systemic Changes

- Reduce disposal of organic materials in landfills by 90% relative to today's levels. Ensure high-quality feedstock for the organic materials management industry and incorporate appropriate backstops (to avoid "diversion for the sake of diversion") as part of the policy development.
- Increase landfill tipping fees to reflect full environmental costs compared to organic materials management methods and support higher-hierarchy organic waste management approaches.
- Foster energy markets for biogas by facilitating electricity generation for e-vehicles through LCFS programs and setting minimum content of renewable natural gas (RNG) in gas utility contracts associated with industrial uses that are not easily converted to electricity.
- Price greenhouse gases (GHG) emissions to incentivize their mitigation through waste reduction and organic materials management.
- Expand the ban of persistent herbicides such as clopyralid, aminopyralid, and picloram to include grass and crops susceptible to contaminating compost.
- Expand the existing renewable portfolio standard by setting new and more ambitious targets in the coming decades.

2. Collaboration improvement

- Establish a statewide working group to develop strategic policy for organic materials management.
- Improve the availability and quality of public data related to organic materials management facilities and their operations.
- Require municipalities to include partnered educational and outreach programs in their contracts with service providers and other collaborators to reduce contamination.
- Establish a standing working group to define types of compostable products that composting facilities can accept, considering their capacity and type of feedstock.

3. Capacity and markets expansion

- Make spreading equipment readily available to farmers through equipment share and financial assistance.
- Incentivize the development of anaerobic digestion projects that include infrastructure cost-sharing or public-private partnerships.
- Provide funding to connect facilities producing biogas and renewable natural gas (RNG) with pipelines and the electrical grid infrastructure.
- Incentivize and provide funding for pilot diversion strategies, such as co-digestion, that leverage existing infrastructure.
- Foster and support community-based and backyard composting.
- Support market expansion for organic treatment byproducts as nutrient fertilizers.

4. Performance improvement

- Increase (training) requirements for acquiring and maintaining a certificate of completion on compost facility operation by increasing training hours and hands-on experience provided by the Washington Organic Recycling Council (WORC) and other organizations.
- Update the state's manual for operating industrial composting by integrating best management practices (BMPs) based on key performance indicators (KPIs) monitoring and available technology.
- Consider using excess steam from industrial and energy sources to treat organic waste collected in urban areas prior to transport east.

5. Permitting revision

- Manage the permitting of solid organic waste management facilities by creating a coordinated process.
- Redesign permitting for composting facilities based on key performance indicator (KPI) ranges according to facility operations plans.
- Establish standards for VOC emissions testing methods required for composting operations to establish compliance with air quality permitting requirements.

- Define standardized measurement methods for odors emitted by organic waste management facilities.
- Proactively define zoning for the development of organic materials management facilities.
- Increase funding for professional training and monitoring equipment at regulatory agencies.

6. Innovation support

- Encourage the development of organic management systems for highly localized anaerobic digesters, in-vessel composting, vermicomposting, effective microorganisms, and bokashi composting operations.
- Provide funding to build, modify, and expand organic materials management facilities that can process food scraps.
- Provide incentives for anaerobic digestion projects such as co-digestion (farm-based and WWTPs) and high-solid anaerobic digesters.
- Provide funding for expansion of the purchase of products generated through organic management, e.g., through coupons or similar mechanisms.
- Create an innovation center (or add to an existing center) for the development and piloting of technologies in organic materials management.

7. Standards improvement

- Update the existing list of chemicals and their permitted levels in organics management products, potentially adding PFAS to the list.
- Require compostable foodservice products to be distinctly colored (green/brown coloration) and labeled so that they can be easily distinguished *if* allowed at facilities.
- Set standards and requirements for the application of digestate products in the state.

8. Contractual processes improvement

- Regionally standardize local governments contracting processes with organic materials management facilities.
- Encourage municipalities to pilot Pay-As-You-Throw (PAYT) collection systems based on weight instead of volume for commercial collection.
- Set bid preferences for renewable fuels like renewable natural gas in government contracts for heavy duty vehicles.
- Implement better systems of source separation through incentives and sanctions.

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Abbreviations

ASP	Aerated Static Pile
ASTM	American Society of Testing and Materials
BCS	Bokashi Composting System
BMP	Best Management Practices
BPI	Biodegradable Products Institute
C:N	Carbon to Nitrogen ratio
C&D	Construction and Demolition
CAFO	Concentrated Animal Feeding Operation
CalRecycle	California Department of Resources Recycling and Recovery
CETA	Clean Energy Transition Act
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon dioxide
Commerce	WA State Department of Commerce
DOE	United States Department of Energy
DOR	Washington State Department of Revenue
DNRP	King County Department of Natural Resources and Parks
Ecology	Washington State Department of Ecology
EIA	Energy Independence Act
EM	Effective Microorganisms
EPA	United States Environmental Protection Agency
EU	European Union
GHG	Greenhouse Gases
GIZ	German Corporation for International Cooperation
ILSR	Institute for Local Self-Reliance
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ITB	Invitation to bid
KC	King County
KPI	Key Performance Indicator
LCFS	Low Carbon Fuel Standard
LFG	Landfill Gas
MEETS	Metered Energy Efficiency Transaction System
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
NMNEOC	Nonmethane, non-ethane organic compounds
NPK	Nitrogen, Phosphorus, and Potassium
OCRW	Organics Contamination Reduction Workgroup
PAYT	Pay-As-You-Throw
PFAS	Per- and polyfluoroalkyl substances
PPA	Power Purchase Agreement
RCW	Revised Code of Washington
REAP	Rural Energy for America Program
RFS	Renewable Fuel Standard Program
RIN	Renewable Identification Number
RNG	Renewable Natural Gas
RPS	Renewable Portfolio Standard
RVO	Renewable Volume Obligation
SPP	Sustainable Purchasing Program
STA	Seal of Testing Program
SW	Solid Waste
TKN	Total Kieldahl Nitrogen
TMECC	Testing Methods for the Examination of Compost and Composting
TP	Total Phosphorus
TSS	Total Suspended Solids
USCC	United States Composting Council
USDA	United States Department of Agriculture
USITC	United States International Trade Commission
UTC	Washington Utilities and Transportation Commission
VOC	Volatile Organic Compounds
WAC	Washington Administrative Code
WORC	Washington Organic Recycling Council
WSDA	WA State Department of Agriculture
WSDOT	WA State Department of Transportation
WSU	Washington State University
WTE	Waste-To-Energy
WWTP	Wastewater Treatment Plant

Photo: Gabriel Jimenez for Unsplash

Chapter 1: Introduction

A formal regulatory structure for the management of organic materials at an industrial scale in Washington State goes back to the *Waste Not Washington Act* of 1989. The system, including programs set by municipalities and the state, has evolved so that by 2017, a total of 1,439,969 tons of organic materials was processed (Ecology, 2017). This success, however, has not been exempt from challenges as policymakers, planners, regulators, researchers, and the industry continue to adapt to new materials, growing population, escalating land prices, and changing regulations. Thus, as of 2017, a roughly equivalent amount of organic waste (1,306,136 tons) continues to be annually landfilled or incinerated (Ecology, 2018a).

Recent attention has focused even more on food waste and food packaging, which continue to burden the state's waste management system and contribute to climate change impacts at landfills.

This first chapter includes the project background, quantitative and qualitative analysis methodology, and a quick summary of the rest of the report's structure.

1.1. Background

The Washington State Department of Ecology (Ecology) defines *organics* as "*carbon-based materials including forest slash, food, yard debris, manures, and other agricultural residues*" (Ecology, n.d.a). Among these materials, food waste arises as a challenging stream because it is highly putrescible (i.e., prone to rot) and likely to carry a higher pathogen load than other materials when it includes meat and fish leftovers (Goldstein et al., 2019). Addressing food waste is an even more pressing problem, though, as its mismanagement poses avoidable environmental and health risks to our communities.

Almost 1/5 of the disposed load in Washington is food waste

Ecology's *2015-2016 Washing*ton *Statewide Waste Characterization Study* showed that disposed organic material makes up 28.5% (1,306,136 tons) of the total disposed waste stream load, by weight, and is higher in the residential waste sector (43%) relative to the commercial sector (27%). Food waste represents 17% (796,094 tons) of disposed materials in Washington (Ecology, 2018a). This challenge is a major climate change issue because the decomposition of food waste in landfills generates significant methane, a potent greenhouse gas.

While landfill Gas (LFG) projects capture methane emissions from landfills with recovery rates ranging from 60 to 90% (EPA, 2020a), their technical and economic feasibility can be limited in many cases. LFG projects also imply nutrient loss and a lesser use of organic materials compared to food recovery and other preferrable management options under the organic waste management hierarchy.

Organic materials are costly to transport because of the highwater content. In locations without other options, cities and businesses are forced to ship the materials miles away to authorized landfills, increasing the overall costs of solid waste management and GHG emissions (King County SWD, 2019). Incinerating food waste is not cost-effective either, due to its high moisture and the corresponding reduction of feedstock available energy.

Although food waste is a current revenue stream for landfills through tipping fees, the derived leachates and the infrastructure and treatment needed to manage them contribute to operational costs, permitting requirements, and associated investment for running these facilities.

Waste management alternatives such as composting and anaerobic digestion can effectively reduce a significant amount of methane emissions. These options also allow the rescue of valuable nutrients for use as fertilizers and soil amendments (Jobson and Khosravi, 2019, Hills et al., 2019, Gilbert et al., 2020a, 2020b).

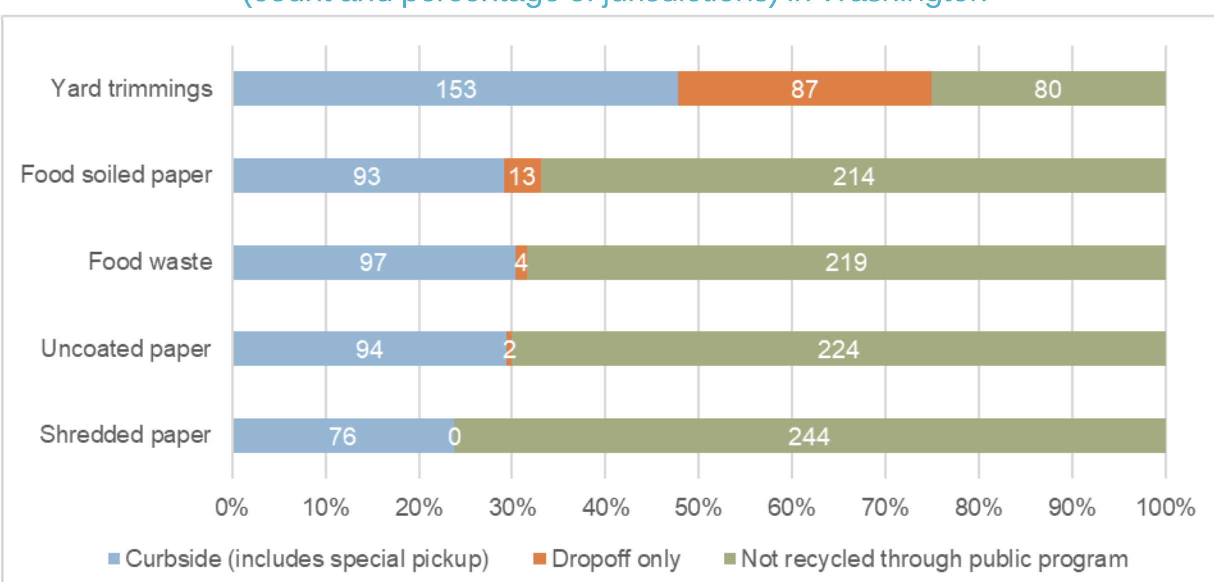
While Washington governments have relatively long experiences managing organic waste, food waste has become more and more of a challenge (Ecology, 2015). Numerous initiatives seek to reduce food waste in the first place and prevent food spoilage through education, outreach, better monitoring, and improved food labeling and industry practices. For edible food, a vast network of food rescue initiatives works to re-distribute food to communities suffering food insecurity (Commerce, 2020; King County SWD, 2019). These approaches are preferred paths to tackle the food waste problem (EPA, 2019; Ecology, n.d.a). The next best choice is the use of food waste for animal feed, which is already a major part of the food industry practices and business models (Commerce, 2020). For the remaining food waste, after all previous approaches - waste prevention, food rescue, and animal feed - have been exhausted, recycling through composting and anaerobic digestion is preferable to landfilling.

Washington's organics management industry has been a national leader

Washington's composting industry is one of the most established in the US. In 2018, the state industry processed 1.28 million tons of organic materials, including 159,574 tons of food waste (Commerce, 2020). Diverted organic materials in Washington also have notably low contamination rates (e.g., 2.6% in Seattle, see SPU, 2018) compared to contamination rates of feedstocks received by facilities in many other states (usually 5-10% in the LA Basin, as reported by interviewees). Low contamination rates impact overall manufacturers' product quality and significantly reduce the tonnage of residual material sent to landfills.

The industry operates under tight financial margins, stringent regulations, and ever-increasing expectations from communities and their authorities (Ma et al., 2013). The sector's response has been a continuous development and expansion of their operations, diversification of their feedstocks, improved management performance, and investment in technology. These advances, however, have not been universal and more work remains to increase infrastructure and collection across the state. For example, in 2019, only 240 out of 320 jurisdictions in Washington State – 75% of the total - provided access to yard debris collection for single-family residents, either curbside or drop-off (Figure 1). Access for curbside collection of food waste is lower, with 101 jurisdictions (23%) allowing food waste to be included with the yard debris. This access is most prevalent near the I-5 corridor, where only one jurisdiction lacks access to both curbside and drop-off sites for residents' food waste (Zero Waste Washington, 2019).

Figure 1 Type of organics collection by jurisdiction (count and percentage of jurisdictions) in Washington



Curbside and drop-off collection is based on status as of October 1, 2019. From Zero Waste Washington, 2019.

Operational issues lead to complaints and restrictions

Composting and other organic materials management facilities pose several potential impacts and risks to their surroundings. Composting facilities emit varying amounts of volatile organic compounds (VOC) and odors. Anaerobic pockets release methane and may increase odor emissions from operations (Ma et al., 2013; O' Neill and Hill, 2020).

Green waste[1] and food waste can attract pests and vermin unless carefully managed, leading to complaints from neighboring communities (Coker, 2016). The generation and management of leachates are also a concern. Even when well contained, leachate may escape and may generate odors if not correctly managed (Goldstein et al., 2019). Finally, compost facilities must be designed to minimize stormwater runoff per WAC 173-350-220.

Industrial composters must address all these issues per Washington State's existing solid waste handling regulations (WAC 173-350-220) and use Best Management Practices (BMPs).[2] Investment in pre-treatment and process technology and instrumentation helps address emissions and odors while also allowing operations to expand when meeting physical and logistical conditions. Close partnerships between public and private actors are necessary for developing the industry, as feedstock inputs and end-markets define the viability of the recycling system (CalRecycle, 2020).

Need for further market expansion and income sources

Organic material processors rely on revenue from tipping fees on the incoming end and sales at the backend. Revenue from manufactured products is the smaller yet critical source of income and depends on multiple factors, including product quality and demand. Products are used as fertilizers and soil amendments. Landscaping operations currently make up most of the market, yet significant potential demand exists in farm operations and land reclamation projects. This potential is currently inhibited due to limited knowledge about the effectiveness of the products, their features and application methods.

Anaerobic digesters are somewhat supported by government incentives because of their GHG mitigation benefit but these facilities still operate under tight and uncertain revenue models.

While the organic waste management industry has taken proactive and voluntary actions to standardize operations as it grows and adapts to market signals, other policies, including financial incentives, are likely needed to facilitate needed growth. Such policies need to be supported by the best available evidence about the industry's operational challenges and the barriers for the incorporation of new materials streams, including the best approaches for processing food waste.

[1] In this report, green waste includes yard debris and agricultural organics, as classified in Ecology (2018a)
[2] For more information see O' Neill and Hill (2020)

Recent legislative and regulatory action addressing organic waste management

Recent initiatives have aimed to improve the performance of the organic management system and to address food waste in Washington as well as reduce contamination, including:

- In 2009, the legislature passed SB 5797 (codified as 70A.205.290 RCW) that exempts certain anaerobic digesters from solid waste permitting requirements. The exemptions are conditioned to facilities that process at least 50% livestock manure and no more than 30% waste-derived materials, among other conditions (WA Legislature, 2009).
- In 2012, SB 5343 (codified as 70A.15.2590) extended provisions related to emissions limits for sulfur dioxide from anaerobic digesters under certain circumstances (WA Legislature, 2012).
- In 2013, the state updated regulatory language regarding the prioritization of organic feedstocks for composting operations (Platt, 2016).
- In 2015, HB 1060 (codified as 70A.200.140) encouraged composting by including it as part of the programs funded by the Waste Reduction, Recycling, and Litter Control Act. These programs are funded by a 0.00015% litter tax on retailer's gross proceeds of consumer products, including food, groceries, beverages and drinks, household paper products, among others (WA Legislature, 2015).
- In 2016, the legislature passed SB 6605 to prevent the spread of disease, plant pathogens, and pests derived from solid waste facilities operations, including composting (WA Legislature, 2016).
- In 2018, HB 2580 established sales, use, and property tax exemptions for anaerobic digestion and landfill facilities generating biogas. See, for example, RCW 82.08.900, 82.12.900, and 84.36.635 (WA Legislature, 2018).
- In 2019, the legislature passed HB 1114 (codified as 70A.205.715 RCW) to reduce food waste to minimize its environmental impacts and fight food insecurity. The law established a goal of reducing food waste sent to the landfill by 50% by 2030, compared to 2015 levels, and required the development of a state plan for reducing wasted food and improving food waste diversion (WA Legislature, 2019a).
- In 2019, HB 1569 (codified as 70A.455.050 RCW) addressed marketing language for compostable products. The law prohibits sales or distribution of products that claim biodegradability but do not meet the American Society of Testing and Materials (ASTM) standards as compostable products or packaging. The bill also requires compostable products to be identifiable through coloration, logos, and similar (WA Legislature, 2019b).
- In 2020, the legislature passed HB 2713 (codified as 43.19A.120 RCW), which encourages local governments that provide residential compost collection to buy back at least 50% of the finished products generated by facilities processing their organic materials. Caveats are included for several circumstances (WA Legislature, 2020).
- In 2020, the legislature passed SB 5323 (codified as 70A.530 RCW) banning thin single-use plastic carry home bags. In 2021, the legislature passed SB 5022 banning certain expanded polystyrene foodware, recreational coolers, and packing peanuts, requiring minimum post-consumer recycled content in beverage and other bottles and jugs and trash bags, and mandating that food establishments only provide utensils, straws, cold cup lids, and condiment packages upon customer request. These two laws aim to reduce plastic contamination in the organic waste stream and provide other benefits.

Local government action

Washington's cities and counties have also taken action to address the management of organic materials within their jurisdictions. Some examples are:

- The City of Tacoma, in 2014, set a goal of diverting 70% of the city's solid waste from landfills by 2028, guided by a Sustainable Materials Management Plan. Starting in 2021, the plan's second phase will consider new regulations and investment in increased capacity to process yard and food waste (City of Tacoma, 2020).
- The City of Seattle banned organics disposal in 2015 – including food waste - in its garbage collection, which allowed for decreased costs for that service (Morris, 2020). The ban resulted from a series of performance improvements of the organics management system since its creation in 1981. In 2008, the city also passed an ordinance requiring all food service products to be recyclable or compostable (City of Seattle, 2009).
- When King County updated its Comprehensive Solid Waste Management Plan in 2019, it incorporated a target to achieve zero waste of resources by 2030, i.e., eliminate the disposal of materials with economic value. The county plans to achieve a 70% recycling goal by 2030 (KC Solid Waste Division, 2019).
- Clark County worked on strong regional integration with the city of Vancouver, exhibiting notable collaboration between the government, haulers, and their main organic waste management processor.

1.2. Project purpose

The purpose of this research project is to:

- Determine the current status of organic waste management in Washington.
- Assess barriers and needs for expanding and improving the system.
- Create recommendations for improvements and potential policy approaches so that the load of organic material to landfills is significantly reduced and the material is managed for optimal environmental benefit.

In addition, this report seeks to orient legislators and decision makers on the best approaches for further reducing the amount of landfilled inedible food waste in Washington following the passage of HB1114 (codified in 70A.205.715 RCW).

1.3. Methodology and Description of the Project

The project comprised the following tasks: (a) Information gathering and depuration, (b) Literature review, (c) Assessment of Washington's current organic waste management, (d) Interviews of industry and agency experts, and (e) Generation of a set of recommendations. We asked interviewees to review the report and the recommendations prior to the report's publication. In this sense, we aimed for a report that assembles the existing knowledge and information about organics management in the state and the collective voices and thoughts of our interviewees. Details about each of these tasks are below.

Information gathering and depuration

We collected information on industrial composting, anaerobic digestion, and other organic waste management systems. We reviewed annual reports submitted to Ecology by permitted industrial composting facilities, as well as some exempt composting facilities required to annually report their activities per WAC 173-350-220. These reports include amounts and types of organic materials composted in industrial-scale facilities, as well as their location, operators, feedstock origin (by county), and compost production, among others. We also reviewed Ecology and other agencies' information (including permits) on industrial composting, permitting, and anaerobic digesters to complement the whole picture of Washington State's organic waste management system. This information was prepared for visualization through tables, maps, and graphs.

Literature review

We conducted a review of the existing reports, journal articles, white papers, presentations, guidance, and more, to improve organics and food waste management in Washington and elsewhere. Explored topics ranged from the status and background of organics collection, hauling, and recycling, legislative initiatives, end-markets and their levers for the use of the finished product to operational, technical, and financial needs for the improvement of organics and food waste management. We systematized and contrasted the findings with what we heard from our interview respondents when elaborating on the recommendations in the final chapter of the report.

Assessment of Washington's current organic waste management

We generated a series of tables, maps, and graphs based on information from industrial composting, anaerobic digestion, and other organics and food waste management indicators. The maps were generated using ArcMap to display organic materials flows. We generated a scale to achieve a consistent characterization of facilities and counties processing volumes, flows, compost production, and permitted capacities to ease their visualization and comparability.

Interviews with industry and agency experts

We conducted a total of 53 interviews with organic waste management experts from the industry, government, consulting sector, and academia. The interviews were conducted either individually or in groups, including a total of 61 persons (

Table 1 shows the distribution of interview respondents by sector and geographical area).

Table 1. Distribution of interviews by sector and region

Area	Industry	Consulting and Academia	Government	Total
Northwest WA	8	2	6	**16**
Southwest WA	7	1	3	**11**
Central WA	2	0	0	**2**
Eastern WA	2	2	2	**6**
Statewide	0	13	4	**17**
Out of the State	0	1	0	**1**
Total	**19**	**19**	**15**	**53**

Note: Appendix 1 shows Washington regions with their corresponding counties

We generated base questionnaires, which we adapted to fit each respondent's background, sector, and profile.

The interviews were semi-structured, where team members and respondents discussed organics management from the interviewees' standpoints. We contacted all of Washington's composting facility operators required to report activities to Ecology in 2018 (per WAC 173-350-220), along with a group of experts and government exponents, through the snowball sampling technique.[3] Interviewees were assured that their comments would be confidential to allow for candid discussions, which is why the findings and recommendations later in this report are generalized and not facility-specific. Appendix 2 characterizes facilities[4] represented by interviewees by facility volume and region. Appendix 3 characterizes interviewees from the government, consulting, and academia sectors by expertise and region.

1.4. Report Structure

The report is structured in seven chapters summarized below:

- Chapter 1 (this chapter) includes background, purpose, and methodology.
- Chapter 2 summarizes organics management system technologies, including industrial composting and complementary organics management system, regulatory framework, and recent trends.
- Chapter 3 describes the status of Washington's industrial composting system, characterizing facilities, feedstocks, inter-county flows, compost production, and end-markets.
- Chapter 4 describes the status of alternative and complementary organic management systems, namely dairy and biosolids digesters, vermicomposting ventures, and others.
- Chapter 5 summarizes our findings regarding barriers and limitations for expanding organic management in Washington, including infrastructure and equipment needs, logistical issues, and regulatory and environmental quality restrictions.
- Chapter 6 identifies potential opportunities for expanding organics management in the state, especially those related to developing technologies, trends, and legislation.
- Chapter 7 presents a set of 38 recommendations for the expansion and improvement of the performance of organics management facilities.

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[3] For more information, see https://www.statisticshowto.com/snowball-sampling/

[4] interviews included representatives from a total of 21 organic management facilities in addition to other government, consulting, and academic research experts.

Chapter 2: Organic Waste Management Technologies and Washington Regulatory Structure

Historically, land application of manure and crop residues onto farmland has fertilized soils and allowed agriculture to flourish in vast areas worldwide. Today, composting, anaerobic digestion, and other techniques facilitate the rescue of nutrients and energy from organic materials. There is also a growing regenerative agriculture movement. Organic materials management methods include those that derive value-added products from feedstocks comprised of organic materials. Incineration and landfilling are not considered organic materials management but instead are considered disposal methods. Incineration and landfilling, however, are included in this report in order to summarize current conditions comprehensively.

This chapter provides a brief overview of management options for organic waste and the current regulatory structure in Washington. Barriers and challenges are covered later in chapter 5.

2.1. Industrial Composting

Composting is the most traditional and widely used system for recycling organic waste (Ricci-Jürgensen et al., 2020). Organic material is decomposed in an aerobic environment. Thermophilic microorganisms digest the materials, consuming the available oxygen and generating high temperatures to produce a stabilized soil amendment and a mix of gases composed mostly of carbon dioxide (Ecology, 2013b). Composting differentiates from anaerobic digestion, in which microorganisms digest materials through biochemical paths without oxygen and usually at lower temperatures.

Benefits

Composting offers multiple environmental (See box) and economic benefits compared to the default landfill disposal or incineration of organic materials. The process recovers nutrients that are valuable for multiple uses, including agriculture, ecological restoration, stormwater pollutant adsorption, and landscaping. Compost is an important soil amendment in agriculture, providing beneficial soil organisms as well as humus, micronutrients, and a slow release of nitrogen, phosphorus, and potassium (USDA, 2015). The impacts on soils are well established and include lowered bulk density, increased infiltration, increased cation exchange capacity, improved moisture cycling, and in some cases, reduced plant pathogen impacts. (De Ceuster and Hoitink, 1999, Martínez-Blanco et al., 2013). Composting also kills pathogens and weed seeds and degrades most chemical pollutants found in the feedstocks used in the process.

Composting provides significant mitigation to climate change by reducing greenhouse gas emissions – especially methane – relative to landfilling and providing carbon sequestration in soils (GMT, 2021). The benefits of the latter has begun to gain traction among climate policymakers because most climate scenarios show that carbon sequestration is critical for limiting global temperatures to below the 1.5°C and 2°C change that the Intergovernmental Panel on Climate Change (IPCC) has determined necessary for preventing catastrophic climate consequences. This climate benefit of composting has been a significant argument for banning the landfill disposal of organic materials and incentivizing industry's expansion in recent years (Sandson et al., 2019). Recent studies have shown that carbon sequestration benefits are even greater than previously thought when cover crops are combined with compost application, according to deeper soil inventories (Tautges et al., 2019, Cernansky, 2019).

Processes

There are multiple scales and end-uses for composting. We focus on industrial-scale processes, generally operating under permits. Namely, those suited to process up to tens of thousands of tons per year. These processes generally follow one or more of the methods below:

- Aerated Static Piles (ASP): This method consists of accumulating organic material in

What is composting and why does it matter?

Composting is the process by which organic materials break down into a soil amendment when placed in an aerobic environment. Compost-amended soil can hold significant quantities of nutrients and moisture, promote the production of beneficial fungi and bacteria, and reduce the need for chemical fertilizers.

Despite these benefits, organic waste still represents 55.7% of materials disposed of in landfills by weight (Ecology, 2018a), with 34% of food waste also disposed through this method. Only an estimated 6% of food waste is composted (Commerce, 2020). The disposal of these organic materials poses environmental consequences as they break down in landfills producing methane, a greenhouse gas that contributes significantly to global climate change (EPA, 2020h).

piles where aerobic degradation occurs under controlled conditions. The aeration of piles can be either passive (natural convection through piping) or active (using fans to blow air in perforated pipes). Ventilation can be positive (towards or into the pile) or negative (outwards from the pile), providing oxygen to sustain the aerobic environment. This method is characterized by its low space footprint requirement and offers the possibility of well-controlled process conditions that enhance product consistency and reduce environmental impacts (EPA, 2016a). These facilities can operate outdoors, under roofs, or indoors.

- Turned Windrows: This composting system consists of the creation of rows of organic material, which are turned at a given frequency. This can be an energy- and labor-intensive technique as it requires frequent turning of materials with machinery, generally compost turners. Piles are typically lower in height and spaced for access between rows, which creates a need for a larger facility space footprint compared to other options. The method is characterized by its simplicity and higher product homogeneity (EPA, 2016a). These facilities generally operate outdoors and, thus, are exposed to weather conditions.
- Turned Mass Beds: This technique involves the creation of elongated piles of materials of relatively low height. Mass beds are then turned at given frequencies to maintain product homogeneity and generally include mechanical ventilation like in-floor aeration systems (CH2M HILL, 2013). Turned mass beds are suitable for indoor or outdoor operation.
- In-Vessel: This method includes in-tunnel and containers that provide an enclosed composting environment that eliminates fugitive emissions. Large-scale systems often include forced aeration and control systems that can maintain semi-optimized conditions (within BMP ranges) and high product homogeneity through key performance indicators (KPIs) monitoring. In-vessel composting can adapt to multiple feedstock streams and facility sizes. Membrane covers such as GORE are not considered in-vessel systems, although they can be used with the other methods described above (EPA, 2016a). Investment in in-vessel systems is usually higher than in other options.

Feedstocks

Composting facilities receive multiple types of organic materials from industrial and commercial activities and municipal solid waste systems that serve as feedstock. The most frequent feedstock types are listed below (Ecology, 2017):

- Yard Debris: Yard debris includes leaves, tree trimmings, grass clippings, and other vegetative waste. It generally comes from residential and commercial sources, and it is often collected through municipal solid waste management systems. Landscapers, haulers (from curbside collection and others), and homeowners drop off loads at transfer stations and or directly at industrial composting or mulching facilities. Yard debris has a wide range of C:N ratios,[5] moisture content, and degradability that can vary during the year from a same source. For example, during spring grass season, facilities that compost only yard debris can struggle to keep the C:N above 20.

- Food Processing Waste: Food processing wastes are generated as byproducts of the food industry and typically have a low C:N ratio, high moisture, and density, and high degradability. Because of the large scale of their generation and high nitrogen availability, they can be valuable additions to green waste streams (yard debris and agricultural organics. This feedstock is prone to rapid decomposition, low pH, and the generation of anaerobic pockets. Thus, food processing wastes require proper management to minimize odors and produce a consistent product.
- Post-Consumer Food Waste: Post-consumer food waste is collected from residential and some commercial or industrial sources. It is a good source of nitrogen as it possesses a low C:N ratio, high moisture, and high biochemical availability. This waste stream has the highest contamination rates among all feedstocks as it can include packaging, and paper products, as well as significant amounts of plastic, glass, and metal contamination. A large part of the problem is customers' confusion when disposing of food waste.
- Agriculture and Industrial Organics: Agriculture and industry organic waste, especially associated with food production, is variable and depends on the type of activity and specific types of organic materials incorporated.
- Manure and Bedding: Animal production operations such as dairy, poultry, and cattle produce manure and bedding feedstocks. Like agriculture and industry organics, the specific characteristics of these waste streams depend on sources, with a range seen from manure (high moisture and nitrogen) to bedding (drier and high in carbon).
- Other Materials: Additional organics sources are land-clearing debris, sawdust and shavings, wood waste, mortalities, biosolids, and paper. These feedstocks can be important sources of nutrients or act as bulking agents.

Operational Factors

Contracting. Industrial composting facilities operate in close relationship with their feedstock providers and haulers. Under municipal solid waste contracts, these permitted facilities can receive their feedstock from haulers regulated by the Washington Utilities and Transportation Commission. Haulers are responsible for collecting and transporting materials to composting facilities, and these parties define tipping fees (which are not regulated). When negotiating contracts, both parties can also include provisions to address contamination issues, community educational outreach, load rejection policies, and load frequencies.

Performance. Facility operation largely depends on the volume and type of processed feedstock.

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[5] The C:N ratio represents the relative mass of Carbon (C) to Nitrogen (N) in a given organic stream.

Certain types of feedstock like food scraps require higher operational standards such as quick movement of the waste into the process, stringent performance management, more frequent inspections, and additional abatement equipment for controlling emissions. Operational controls need to consider the volume of production, and they can range from entirely manual operation to fully automated aeration systems. Operators generally include screens to control contamination and screens and grinders to optimize particle size for degradation and the final product's format. Operators also control air emissions and leakages through infrastructure (e.g., concrete floor), equipment (e.g., biofilters and scrubbers), materials (e.g., cover textiles), and Best Management Practices (BMPs).

End-markets. Compost is a valuable product that has a variety of uses and end-markets. It functions as a soil amendment for landscaping and gardening and as part of mulch in agriculture. Compost is also blended with soils and other materials for erosion control and landscaping along highways, in stormwater management systems, and in restoration and bioremediation projects (EPA, 2016b). Compost facility operators may create a variety of products for different markets by varying screen size (i.e., particle size) or blending with sand, soil, and other amendments. Facility operators, thus, consider end-market needs when determining their accepted types of feedstock and operational conditions.

Compost facilities usually operate under tight financial margins. Income is obtained from two primary sources: tipping fees for receiving waste loads (typically 70-90% of revenue) and sales of their products which may include compost, different grades of soil, mulch, and chipped wood (10-30% of revenue). The ratio between these two revenue sources varies depending on product quality, existing demand, and tipping fees.

Composters can increase feedstock volume consistency by contracting with haulers, cities, developers, landscapers, and others. They can also create more stable markets by contracting with wholesalers, landscapers, agencies, and others for their products.

Demand for compost is driven by customers' perception of compost quality, which closely relates to the amount of contamination, degree of maturity, organic certification, and nutrient quantity and availability. In the case of organic certification, USDA's National Organic Program requires compost to meet standards that ensure the absence of contamination and pathogens (§ 205.203(c) and § 205.602) (USDA, 2011). USCC's Seal of Testing Assurance (STA) program ensures a basic compost quality and has been instrumental in standardizing compost laboratory testing and reporting.

Technology improvements and innovation

Industrial composting continues to innovate its methodologies and technologies to improve compost quality and address the complexities of organics management, particularly working to apply new science in the design and operation of composting facilities.

Although vermicomposting (i.e., worm composting) is not a new technique, some companies are starting to use it to manage significant volumes of wastewater (Dore et al., 2019, Chow, 2016). Another technique that some compost operators are testing is Bokashi Composting System (BCS), which is an anaerobic, fermentation process based on the use of Effective Microorganisms (EM) to increase the composting process performance and speed (Ecology, 2013b). Other technologies based on microorganisms developed through fermentation continue to be explored by the scientific community (UC Riverside, 2021).

Compost technology also continues to adapt to the increasing demand for facilities to process more food waste, compostable food service products and packaging and meet tighter regulations. For example, in-vessel compost systems can address some of these targeted applications, while aerated static pile systems are expanding in use because they can operate efficiently in areas with limited physical space. Technologies for ventilation, mechanical processing, and automatic control also continue to improve performance and address market challenges. GORE covers are relatively economical options that help reduce odors and control the temperature and aeration conditions of the piles. Proper aeration and operation allow facilities to take advantage of these membranes' emission control and increase throughput performance (GORE, n.d.).

2.2. Anaerobic Digestion

Anaerobic digestion can be used to process various types of organic waste, including manure, food scraps, sewage sludge[6] and industrial organic residues (EPA, 2020b). These systems use microbes to break down organic materials in an anoxic environment – that is, in the absence of oxygen – to produce biogas and digestate effluent (liquid discharges). Biogas is mostly composed of carbon dioxide (CO_2) and methane (CH_4), along with much smaller amounts of water (H_2O) and trace residual gases, and can be used as a fuel (EPA, 2020b). Digestate is made up of fibers and other organic substances not digested during the process. It contains nutrients that make it valuable as a fertilizer (Gilbert et al., 2020a). Although requiring further processing and maturation to reduce pathogens, digestate can be used for land application, especially when digesters are located within or close to agricultural activities.

There are over 1,500 anaerobic digesters producing biogas in the United States in all 50 states: 255 anaerobic digesters on farms, 1,269 water resource recovery facilities using an anaerobic digester (with around 860 currently using their biogas), and 66 stand-alone systems that digest food waste (ABC, 2018). EPA and some states, through their climate policies, have supported farm-based anaerobic digesters because they can mitigate significant carbon emissions (EPA, 2020a).

Nationally, potential sites where the industry could expand are numerous, with over 14,000 sites identified for potential development, including:

- 8,574 dairy, poultry, and swine farms.
- 3,878 water resource recovery facilities.
- 2,036 food scrap-only systems (ABC, 2018).

[6] *Sewage sludge* is the solid, semisolid, or liquid residue generated during the treatment of domestic sewage in a treatment works. *Biosolids* are produced by treating sewage sludge to meet certain quality standards that allow it to be applied to the land, per WAC 173-308-005

Biogas Uses

Biogas produced in anaerobic digestion can be used in two main ways:

- **Heat and Electricity Generation**: Biogas can be combusted to obtain heat and electrical power injected into the grid. In the case of using combined heat and power (CHP) systems, the process' residual heat is recirculated for thermal preparation of feedstock before its digestion. Its viability is subject to fluctuations and long-term trends in the electricity market and incentives/policies.
- **Renewable Natural Gas**: Another option is removal of CO2, water, and trace gases from biogas to generate renewable natural gas, which can be used directly to fuel CNG fleets or injected into natural gas pipelines. The RNG can also be converted to bio-hydrogen and used in power to fuel technology.

Caveats on biogas use

- There is skepticism about the use of renewable natural gas as a wholesale replacement of petrochemicals. As highlighted by Feinstein and de Place (2021) and Feedback (2020), the most serious concerns are:
- There is not nearly enough potential RNG to replace natural gas. A shift to RNG broadly is not feasible and thus it should be limited to industries that cannot easily replace gas with electricity. Residential and commercial sectors should easily convert to all-electric clean power.
- RNG is expensive compared to existing natural gas and its inclusion would significantly increase bills for commercial and residential customers.
- RNG is involves the same emissions concerns as conventional natural gas as it travels through leaky distribution pipelines and is burned in appliances. It does provide a net carbon benefit, though, relative to natural gas when it is sourced from landfills or anaerobic digestion of organic materials, including that from wastewater treatment plants.
- Care should be taken that RNG projects don't incentivize practices like concentrated animal feedstock operations (CAFOs) that should be reduced by other means, such as pasture raising livestock.
- RNG could be being used a greenwashing tool. Some industry actors are developing public relations campaigns to convince the public and decision-makers that RNG blended with natural gas is a quick and beneficial solution for combatting climate change. Many experts strongly disagree and are concerned that RNG is a side path from needed more effective actions such as conversion to electrification.

The most prevalent types of anaerobic digesters are:

- **Covered Lagoon**: Primarily used in agricultural or industrial settings to treat low-solids, high volume waste, for either flare or biogas utilization. These facilities benefit from warm climates that increase biogas production at ambient temperatures.
- **High-Rate Digesters**: Primarily used at high-strength industrial wastewater producers like breweries or fruit juice processors because of the capacity of systems to quickly treat high flows with readily digestible sugars in an efficient manner.
- **Low-Rate Slurry Digesters**: The most common application used at wastewater treatment facilities for processing sludges and at farm manure projects where covered lagoon is not feasible. Processed slurries are "wet," typically having less than 15% total solids content.
- **High-Solids Digesters** (also known as dry digesters): Can process feedstocks with more than 15% of solids and have gained increased attention due to their relatively smaller size and higher organic loading rate compared to low-solids facilities (EPA, 2020c). These digesters have the potential for processing food scraps, but high investment and operational costs have created barriers to significant expansion (Fagbohungbe et al., 2015).

Pros and cons of anaerobic digestion

Anaerobic digestion offers some advantages relative to composting. By enclosing the digestion process, anaerobic digestion occupies less physical space than outdoor composting operations while also providing more effective odor control during the digestion process (Ecology, 2013b). Revenue streams of anaerobic digestion operations are also more diversified than those of composting, by allowing operators to use biogas for multiple purposes (see sidebox on previous page). Low land usage, high throughput, and limited wastewater generation make digesters worth considering for processing organic waste in urban areas, especially food scraps. Biogas (see sidebox) is suitable for heating, electricity generation, fuel (compressed natural gas), bio-hydrogen, or being transformed and injected into pipelines as renewable natural gas (CA Water Boards, 2019). This last option appears the most economically attractive in the Pacific Northwest region, mostly because of the low electrical energy prices (WSU Energy Program 2018a).

On the other hand, anaerobic digestion facilities have several challenges. They usually require higher capital investments than most compost facilities, presenting payback periods that can extend beyond ten years. Some RNG projects, however, have quick paybacks because of high credit prices received. Also, the specific use of the generated RNG needs careful consideration (See sidebox on page 16).

Anaerobic digestion operates in an enclosed space with flammable gases such as methane, requiring a complex process control system, stringent operation standards, and facing perceived risks from surrounding community members. Many facilities rely on grants and revenue dependent on climate change mitigation plans and clean fuel standards, subject to price variability and policy changes (CA Water Boards, 2019).

Anaerobic digestion facilities are sensitive to the composition or quality of incoming feedstock which can impact the microbiology inside the reactor (thus affecting performance) or cause accumulation sand from inert material. Digesters also tend to generate large quantities of ammonia that needs to be controlled and managed. Biogas requires further processing to eliminate hydrogen sulfide impurity or transform it into SO2. Digesters are also criticized because of their ties to concentrated animal feeding operations (CAFO) due to costs and scale, while also sharing pipeline infrastructure with the fossil fuel industry.

Digesters produce digestate that is carbon, fibrous, and nutrient rich but requires expensive post-treatment to be stabilized, to address the odor, and be made marketable. These requirements make these products less competitive compared to compost, other organic products, and stable and broadly widespread fertilizers markets. These markets are diverse, and customers have difficulties differentiating the many existing alternatives' nutrient value and applications.

Like composting operations, anaerobic digestion facilities operate under tight financial margins. This limitation is primarily due to the high investment needed for construction and operations, which is also accompanied by highly discounted funding due to concerns in the long-term viability of federal and state credit pricing. Biogas utilization competes with other options for carbon reduction, and it is subject to short- and long-term variations in the price of gas and electricity.

Co-digestion of food waste

Anaerobic digestion usually involves feedstocks such as biosolids and manure that are relatively low in their biogas production potential and thus financial viability. Co-digestion is a method to increase biogas production by incorporating additional waste streams, such as food waste, into existing digesters with excess capacity available at wastewater treatment plants, farm digesters, and composting plants (CA Water Boards, 2019, AgSTAR, 2012). The addition of this waste provides new funding sources for such facilities through added biogas and tipping fees while also potentially increasing the nutrient value of the digestate (EPA, 2020d).

Historically, co-digestion projects have utilized industrial wastewater and solids that are not suitable for landfills due to their consistency (measured through a slump test) or transportation costs. Recently, considerable interest has developed in incorporating wasted food into existing digesters. To prepare commercial food waste for co-digestion, de-packaging equipment is needed to mechanically separate packaging from food scraps. The created slurry is then screened for large chunks, such as bones. Diverting these food waste streams allows certain transfer station operators to increase their revenue by lowering their tipping fees and shipping costs (EPA, 2020d).

2.3. Organic Waste Management Alternatives

According to Washington's Organic Management Hierarchy (Figure 2), the highest environmental preference is to prevent waste in the first place. If avoiding waste is impossible, organic material should be used for human consumption through recovery programs and food banks, for example. If food recovery is not possible, animal feeding should be considered. The next choice is on-site waste management through on-site composting, modular digesters, and chipping. Lower priority is off-site management through industrial composting and anaerobic digestion due to their costs and environmental impacts involved in hauling and larger-scale impacts. Lower still in the hierarchy are incineration and landfill disposal with energy recovery. Lower hierarchy options are disposal methods like landfills and incineration without energy recovery. The lowest is open burn. The lower hierarchy options are briefly described in this section.

Land Application

Land application is the spreading or injection of organic material into soil as a conditioner or fertilizer. Depending on the material type, agricultural operations are allowed to use this technique without permits for manure, food processing waste, and crop residues. Solid waste land application permits, and water quality discharge permits are required for land application of industrial food processing wastes. This latter approach is particularly used in the Columbia basin where many food processers are located. Liquid digestate can also be land applied – either under a Dairy Nutrient Management Plan or under a land application permit.

Land application is the main management option for biosolids nationwide. In Washington State, approximately 85% of biosolids are land applied (EPA, 2020e, Ecology, n.d.e.). Biosolids

Figure 2. Washington State Preferred Organics Management Organics Management Hierarchy

Source: Ecology (2016)

are land applied in nonpublic contact sites (i.e., agricultural land, forests, and reclamation sites) and some public contact sites (i.e., public parks, plant nurseries, roadsides, and golf courses).

Land application of organic materials identified as solid waste management is regulated under rates under waste discharge permits. Additional categories of organic materials can also be land applied without requiring permits: compost, and vermicomposting and other organic material handling activities (WAC 173-350-020, -100, and - WAC 173-350-230 unless the operation meets conditions that ensure they are beneficial and do not threaten humans and the environment (WAC 173-350-200). Agricultural and food processing waste can be land applied without requiring a permit if performed at agronomic

225). Digestate can also be land applied without permits if the digester complies with the terms and conditions from exemption and the digestate is land applied under a dairy nutrient management plan. Outside of those conditions, land application of digestate requires a permit.

Biosolid land application regulations include requirements to reduce impacts to groundwater and surface water streams and limitations on the type and amount of material applied per area. Consequently, this method is generally performed in large areas such as agricultural land, golf courses, and military fields. Per WAC 173-350-230, permit exemptions are granted for sites that land apply organics at agronomic rates, this is, at a rate that achieves realistic yields and minimize the movement of nutrients to surface and ground waters (WAC 16-611-010). Per WAC 173-308-170, biosolids that are land applied are classified as Class A, which have undergone pathogen reduction and vector attraction reduction processes, and Class B, which requires the biosolids to significantly reduce pathogens before crops are harvested, used as animal feed or come into contact with the public (EPA, 2020f).

Energy Recovery and Incineration

Combustion of organic materials includes energy recovery and incineration (a.k.a. Waste-To-Energy). These methods produce gaseous, liquid, and solid byproducts. Incineration can allow for partial energy recovery, although such revenue only compensates for operational costs and does not fully cover these costs. These methods can be categorized according to their process temperature (GIZ, 2017):

- Incineration is conducted with excess oxygen at feedstock materials' autothermic combustion temperature. Incineration ignition temperatures usually range between 850° and 1,450°C.[7]
- Pyrolysis/Gasification is conducted with controls on the amount of combustion oxygen and temperature. Depending on the combustion temperatures, these methods fall into three ranges: smoldering (400°-600°C), pyrolysis (500°-800°C), and gasification (800°-1,000°C)[8]. Some pyrolysis systems produce a solid end-product called biochar.

These methods create residues that are usually disposed in landfills. Energy recovery and solid byproducts such as biochar can generate revenue for operations (GIZ, 2017). The industry and academic researchers continue to study the benefits and risks of incorporating biochar – a pyrolysis product - in agriculture and composting operations (WSU, 2018b).

Major concerns with this technology center around environmental justice issues and include challenges with toxic emissions, operational knowledge and training, and hazardous waste management risks (GIZ, 2017). Also, most food waste does not yield net energy gains as it is wet when incinerated, which is why this method receives the lowest priority in the organic waste management hierarchy.

[7] Approximately between 1,560° and 2,640°F

[8] Temperatures ranges in Fahrenheit degrees are approximately as follows: Smoldering (750°-1,110°F), Pyrolysis (930°-1,470°F), and Gasification (1,470°-1,830°F).

Outdoor Burning

Outdoor burning is used to manage some organic waste across Washington State. Burning classifications include:

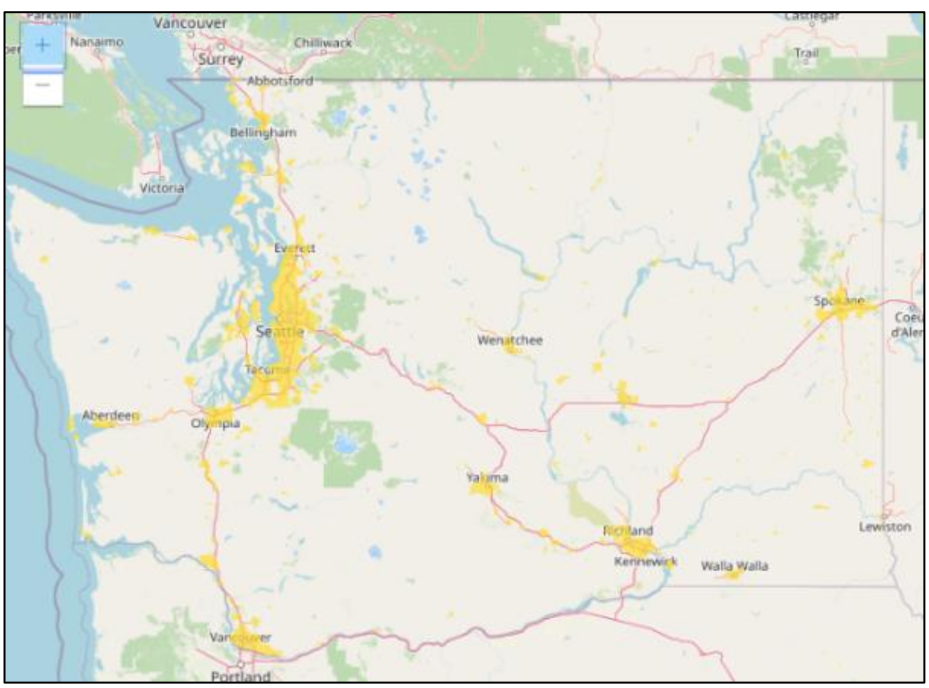
- Commercial agricultural burning is the burning of organic debris related to agricultural operations. It is performed when no practical alternative is reasonably available, and it is regulated by 173-430 WAC.
- Land clearing pertains to the burning of trees, stumps, shrubs, or other natural vegetation from land clearing projects.
- Residential burning includes the burning of household yard debris such as leaves, grass, brush, and other yard trimmings. This type of residential burning is allowed in certain areas of the state. Burning of yard debris within an urban growth area (UGA) is prohibited (see
- Figure 3 for UGAs in Washington).
- Silvicultural burning concerns purposeful burning in forest lands.

Outdoor pile burning systems can be used to produce biochar, which has lower air pollution than open burning and results in a soil amending end-product.

Silvicultural burning is regulated by the Washington Department of Natural Resources (Ecology, n.d.h). Permits can be required for agricultural operations, fire training, land clearing, residential, silvicultural activities, and special burn permits. Issuance depends on the location, size, and time of the year of burning Danger" events can limit burning at any given time (DNR, n.d.).

Outdoor burning releases greenhouse gases into the atmosphere, potentially pollutes water and soil, and may cause health problems and wildfires (Ecology, n.d.i).

Figure 3. Washington Urban Growth Areas (UGA)



Source: Ecology (n.d.g)

Landfill Disposal

Landfill disposal is one of the least preferable waste management options because of the loss of resources and, for organic materials, nutrients. Furthermore, the slow degradation of the organic matter creates methane which is a potent greenhouse gas. Landfills can capture methane through landfill gas energy recovery facilities that containerize the waste in cells and recover the gas using a series of perforated pipes. Gas emitted during the anaerobic degradation stationary phase of the organic material is captured (60 to 90%, see EPA, 2020b), although such capture only begins once cells are sealed (degradation is ongoing while the cell is still receiving waste). The degradation of organic waste under landfills' anaerobic environment and the presence of chemicals and inert materials significantly slows down the gas recovery process.

Landfills emit odors and attract vectors, which makes it preferable that they be located far from residential and industrial zones, which, in turn, increases total costs and emissions associated with the transportation of waste. Furthermore, the disposal of organic waste at landfills involves the loss of nutrients and minerals.

Landfill disposal with energy recovery is a preferable waste management option to sites flaring methane, but they are limited to only controlling a fraction of landfill lifecycle emissions. In this sense, this type of project does not provide a renewable energy source and still contributes significantly to greenhouse gas emissions.

Once landfills reach their capacity and are closed, long-term monitoring is required because residual gas may be emitted and leaching of fluids can contaminate groundwater or surface water (EPA, 2020g).

2.4. Regulatory Framework

Under Washington law, organic waste management facilities are regulated for siting, operations, air emissions, water discharges, and related activities such as hauling and end-markets.

Organic solid waste regulation

- Per WAC 173-350-220, local jurisdictional health authorities regulate permitted compost facilities and Ecology regulates permit exempt facilities. Composting facilities with over 25 cubic yards of materials on-site are required to notify and report to their regulating authorities.[9] These facilities are required to obtain permits and comply with reporting, safety, and testing requirements. A variety of permit exemptions cover composting operations, including farms, nurseries, community gardens, and home composting (Table 220-A in WAC 173-350-220). Conditional permit exemptions are

[9] Although exempted from reporting and notifying, compost operations with less than 25 cubic yards of materials on site are still regulated by health departments as they must adhere to performance standards (WAC 173-350-040). Alternative standards apply to methods excluded from the solid waste handling standards in WAC 173-350-020, composting used as a treatment for contaminated soil or contaminated dredged material regulated under WAC 173-350-320 or 173-350-490, anaerobic digesters regulated under WAC 173-350-250, treatment of liquid or solid wastes in digesters regulated under WAC 173-350-330, composting of bovine and equine carcasses for producers subject to RCW 70.95.306, and composting biosolids when managed under chapter 173-308 WAC, Biosolids management.

granted to facilities processing up to 250 cubic yards at any one time and less than 1,000 cubic yards a year. Higher thresholds are allowed for facilities processing only yard debris, crop residues and other agricultural waste, manure and bedding, and bulking agents. Farms with composting facilities that distribute or sell material off-site are subject to notification and reporting requirements.

- Anaerobic digesters (WAC 173-350-250) processing more than 25 cubic yards of material on-site are subject to notification and reporting requirements[10] and must obtain permits or comply with reporting, testing, and must meet quality standards if materials are distributed off-site. Digestate can be distributed off-site by complying with the conditions described in Table 250-A, such as adhering to compost quality standards, being registered as a fertilizer, or being land applied under a state waste discharge or land application permit.
- Conditional permit exemptions are granted to facilities processing less than 250 cubic yards of material on-site. Digesters exclusively processing certain types of materials are also conditionally permit exempt: livestock manure and pre-consumer food waste, typically waste from food processors. No post-consumer food waste is allowed.
- Local public health departments regulate operations within their county limits, granting permits that define location, operational standards, applicability, and more (WAC, § 173-350-710).
- The Washington State Department of Agriculture (WSDA) regulates agricultural activities operations, standards, effluents, and certifications. The WSDA Organic Program inspects and certifies farms to meet the United States Department of Agriculture (USDA) standards. The department also implements the Dairy Nutrient Management Program (under RCW, § 90.64).
- Organic waste management facilities are required to obtain permits when siting new or expanding facilities if meeting specific volume or operational characteristics. Operators must contact each regulating agency to check for risks posed or impacts on groundwater, soil, flooding, surface water, capacity, and toxic air emissions, among others (RCW, § 70.205.110, Ecology, 2013a).

Air quality regulation

- Permitted facilities must follow air emission general standards under WAC 173-400-040 and comply with other applicable local, state, and federal laws and regulations Air permits, issued and overseen by either Ecology or Clean Air Agencies (see Figure 4), include requirements for maximum emission levels, performance standards, and abatement technology. Beyond performance standards, there are no specific standards related to siting composting facilities.

[10] Anaerobic digesters below the reporting threshold stated in WAC 173-350-250 are still regulated by health departments as they must adhere to performance standards (WAC 173-350-040). Alternative standards apply to for storage or treatment of solid or liquid wastes in surface impoundments or tanks (WAC 173-350-330), anaerobic digesters regulated in accordance with chapter 90.48 RCW (water pollution control), and anaerobic digesters regulated in accordance with chapter 173-308 WAC (Biosolids management).

- Major air emission sources are required to comply with the federal Clean Air Act's Title V, which can be costly. The threshold for sources subject to this federal regulation is 100 tons/year of any criteria pollutant, including volatile organic compounds. Facility developers, either in construction or expansion phases, try to avoid reaching this threshold by implementing BMPs monitored through key performance indicators (KPIs). Compost operations are estimated to emit large amounts of these chemicals under the current methodology based on emission factors. This issue is controversial and is discussed more in Section 5.3.

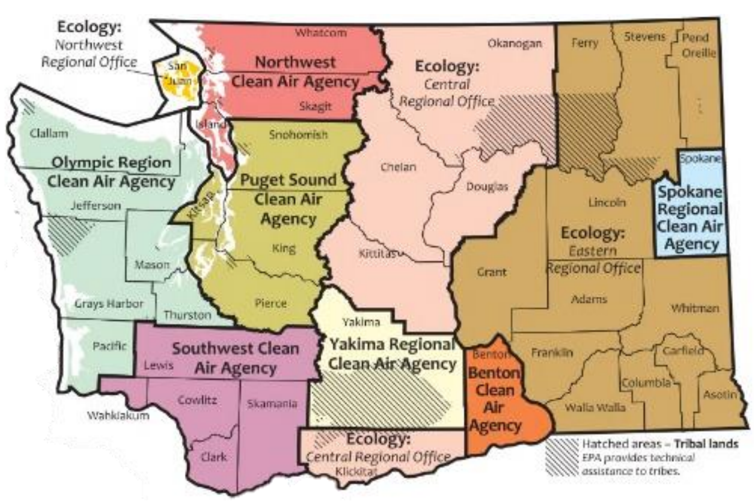
Water quality regulation

- Ecology's Water Quality Program regulates statewide stormwater water discharges from industrial installations, including waste management facilities.
- Compost facilities are regulated under WAC 173-350-220 concerning their surface impoundments and tanks. Tanks used to store leachate must also meet specific design standards described in (4)(b) of WAC 173-350-330. The regulations require that the location, design, monitoring, and operation of surface impoundments and tanks safeguard public health.
- Anaerobic digesters must meet design standards for tanks and impoundments under WAC 173-350-250 and WAC 173-350-330.

Transportation regulation

- The Washington Utilities and Transportation Commission (UTC) regulates solid waste carriers and pipeline operators, including defining service areas, tariffs, fees, and operational standards (UTC, 2016). These companies are required to follow WAC Chapter 480-70, which determines standards regarding public safety, fair practices, just and reasonable charges, and nondiscriminatory application of rates, among others.

Figure 4. Washington Clean Air Agencies



Source: Ecology (2020a)

Chapter 3: Current Status of Industrial Composting in Washington State

In 2019, Washington had 58 permitted compost facilities, including 45 facilities regulated under WAC 173-350-220 and 13 facilities that manage biosolids and are regulated under WAC 173-308. This chapter describes the status of the amount and types of material processed at these facilities in 2018, as well as flow of the material between counties, including feedstock and finished compost. 2019 data are presented at the end of the chapter for comparison purposes.

3.1. Status of composting facilities in Washington

In Washington, permitted compost facilities encompass industrial facilities and permitted on-site facilities, such as those at correctional buildings and university campuses (Commerce, 2020). These operations process various feedstocks, including yard debris, crop residues, manure, bedding, and bulking agents. Farms, nurseries, community gardens, and home composting are allowed to operate as a solid waste permit-exempt facilities (per WAC 173-350-220). Furthermore, farms that compost on-site up to 1,000 cubic yards at any one time are exempted from reporting if that compost is not distributed off-site. Biosolids management facilities that compost or process solids from wastewater treatment plants are regulated separately. [11]

[11] Biosolids are organic materials derived from treating wastewater that is often applied to agricultural lands, forests and gardens (EPA, 2020i).

For purposes of clarity, the analysis that follows uses the term "facilities" to refer to all permitted and permit-exempt facilities required to report their annual throughput and operations in compliance with WAC 173-350-230 in 2018. Facilities not required to report under Table 220-A are excluded from the analysis.

Location of facilities

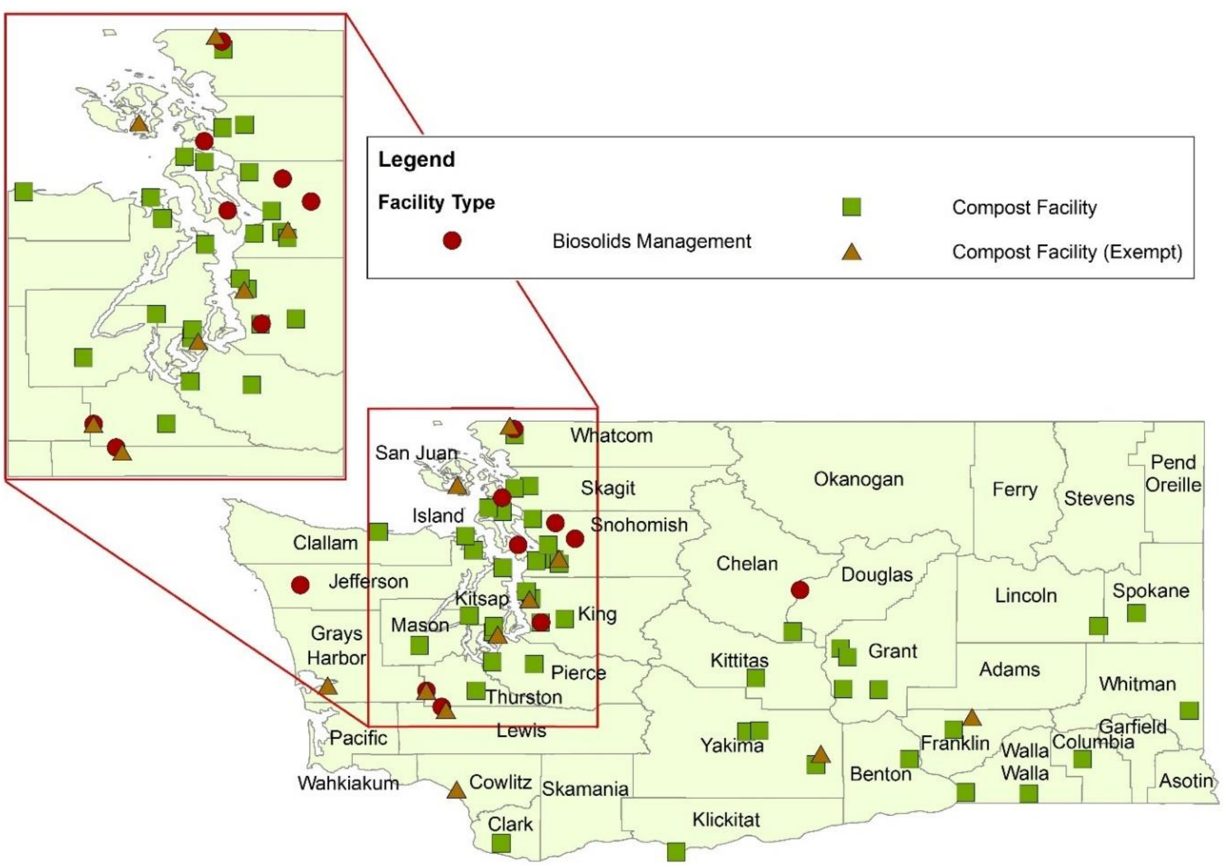
Facilities that operated (Figure 5) in Washington during 2018 are concentrated on the western side of the state (see details in Appendix 4):

Permitted facilities: More than half (26) of the state's industrial composting facilities are located in the western region, with the rest (18) scattered throughout eastern counties (Figure 5).

- Permit-exempt facilities: Nine permit-exempt compost facilities are in the western region, with two in the east.
- Biosolids composting facilities: All but one of Washington's biosolids composting management facilities are located in western Washington.

A total of 11 counties did not have composting operations reporting to Ecology during 2018: Okanogan, Ferry, Stevens, Douglas, and Pend Oreille (northeast), Pacific, Wahkiakum, and Skamania (southwest), and Adams, Garfield, and Asotin (southeast). Details of all characterized facilities' permit status, processing capacity, and site capacity can be found in Appendix 4.

Figure 5. Industrial composting facilities operating in Washington during 2018, by type of operation

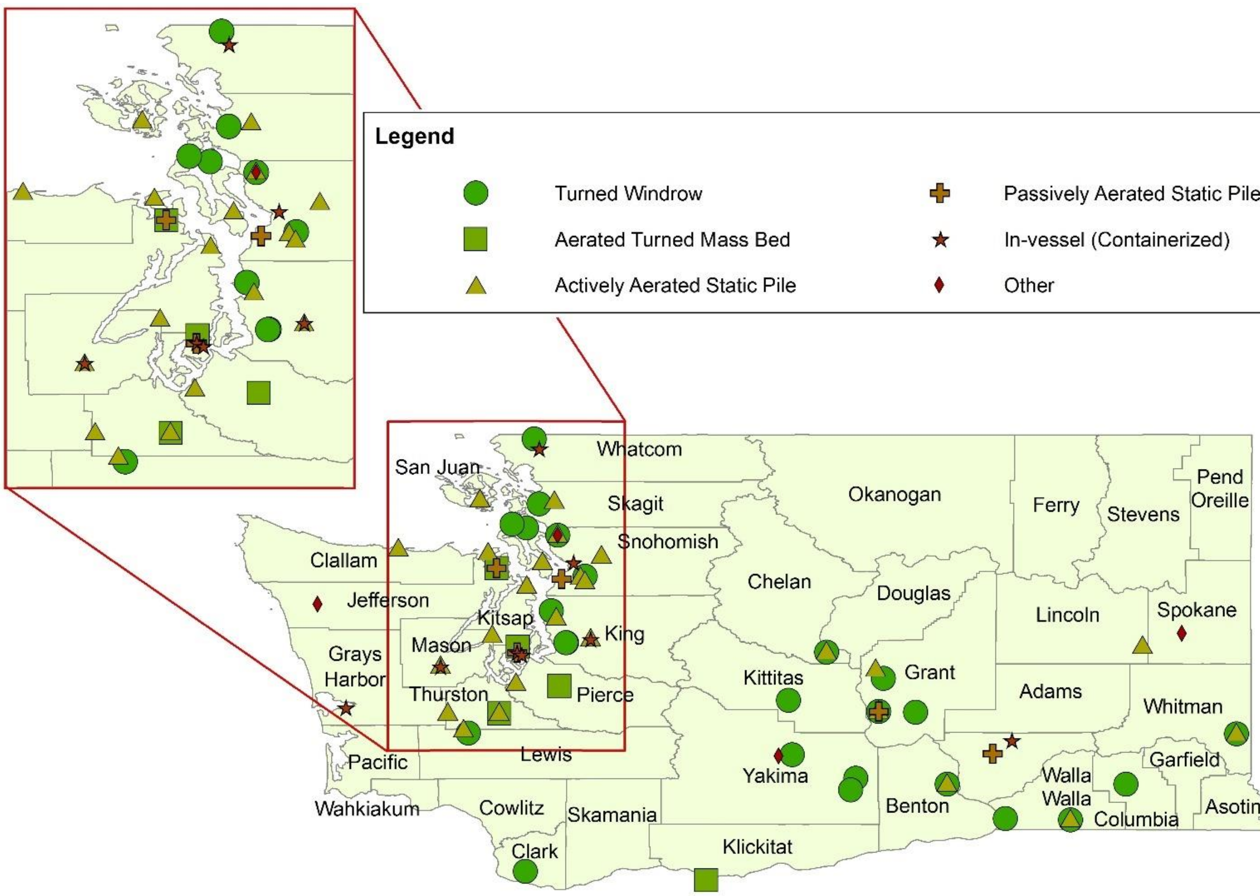


Map shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Detail included in Appendix 4

Composting methods

In western Washington, the most commonly used technologies were turned windrow and actively aerated static pile (i.e., using fans). In eastern and central Washington, 13 out of 20 facilities use the turned windrow method. The disparity between aerated static pile methods in western and more urbanized areas compared to eastern Washington likely reflects the larger volumes of materials processed and the limitation of land. A total of 11 facilities use more than one composting method, usually a combination of aerated static pile and in-vessel technology west of the Cascades and aerated static pile paired with aerated turned windrows on the eastside (Figure 6).

Figure 6. Industrial composting facilities operating in Washington during 2018, by composting method

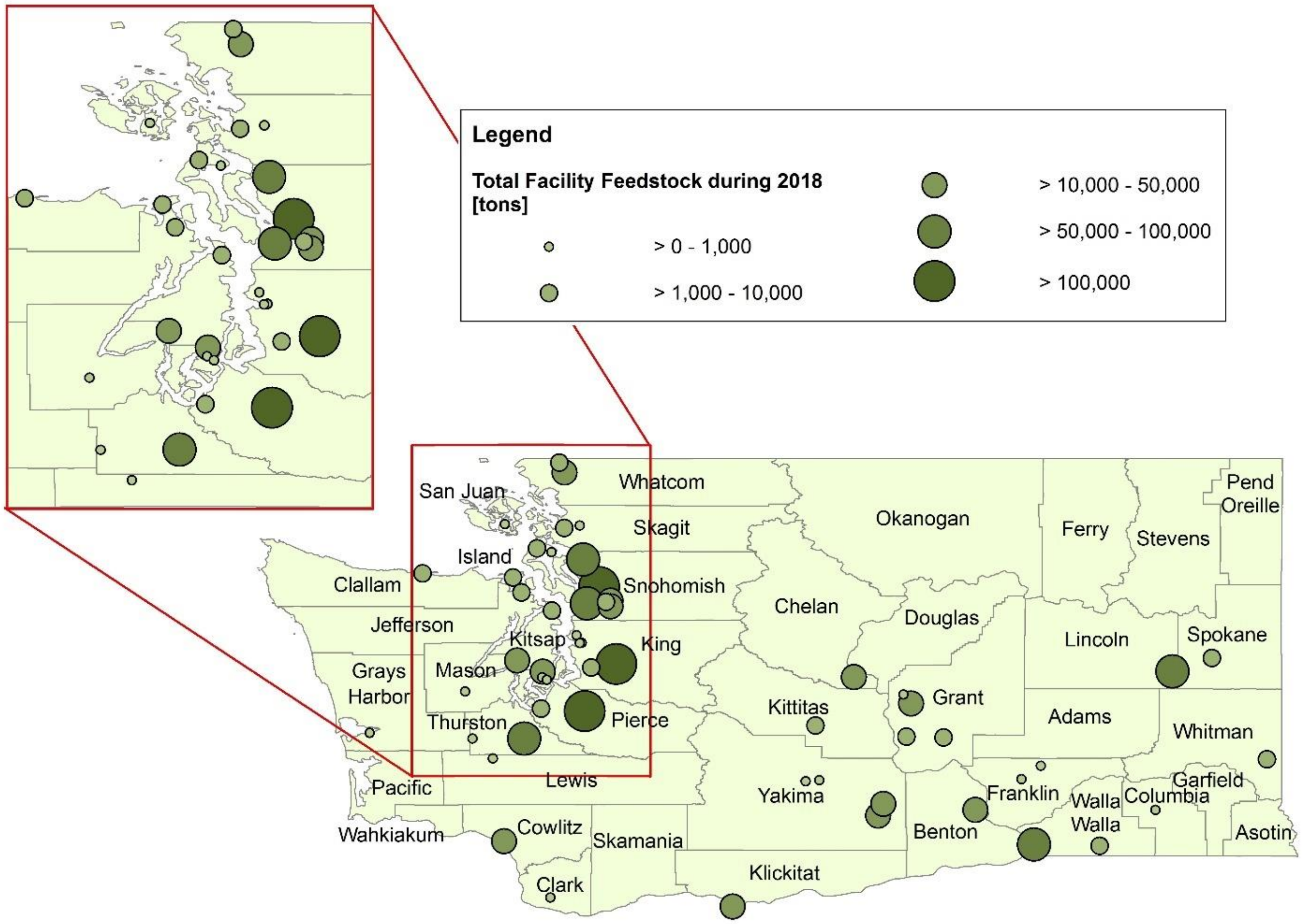


Map shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the map. Detail included in Appendix 4.

Materials processed

Reflecting the state's population distribution, the highest volumes of organic materials are processed on the west side (see Appendix 4 for details). This region includes three facilities that processed more than 100,000 tons of feedstock and three of five facilities that processed between 50,000 and 100,000 tons (Figure 7). In Eastern Washington, the largest permitted composting operations are in the Lincoln and Walla Walla counties (84,251 and 61,020 tons, respectively).

Figure 7. Industrial composting facilities operating in Washington during 2018, by total organic material processed



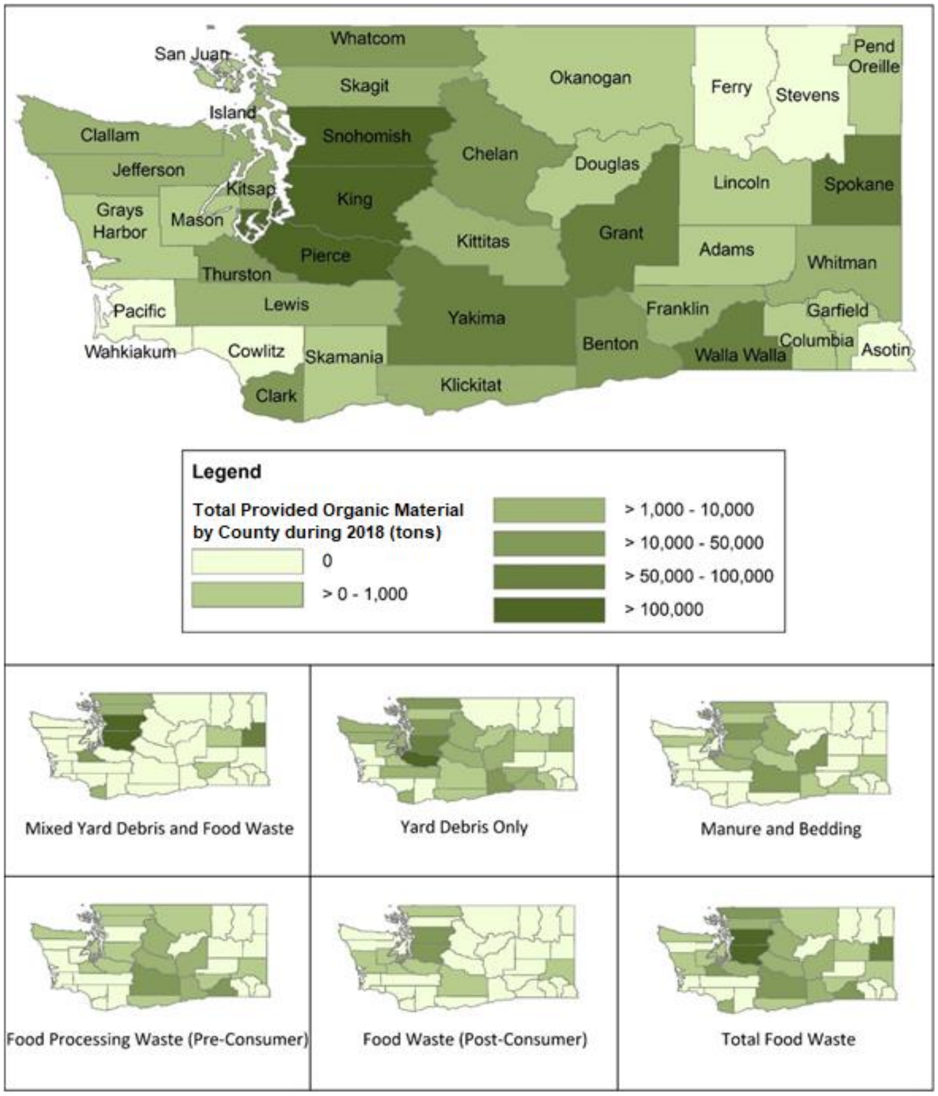
Map shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the map. Detail included in Appendix 4.

3.2 Feedstock volumes and material types

Snohomish, King, and Pierce counties generated the most organic material in 2018, destined for composting, each having collection volumes greater than 100,000 tons (Figure 7). As seen in the map insets, these highly populated areas have the highest amounts of generated mixed and single-stream yard debris. Other counties with high feedstock generation volumes (i.e., greater than 50,000 tons) included Thurston, Clark, Yakima, Grant, Walla Walla, and Spokane. As would be expected, counties with the largest generation of organic material are the same as those that have the greatest number of composting facilities (Figure 8).

Yard debris is widely used as feedstock throughout the state. Beyond that, the distribution of volumes and types of organic waste feedstocks corresponds with the state's urban/rural characteristics. Four counties - Snohomish, King, Pierce, and Spokane - have high rates of generation of mixed yard debris and food waste collection. Manure and bedding feedstocks have highest generation in Snohomish, Yakima, and Grant counties. Pre-consumer food processing feedstock is highest from Yakima and Walla Walla counties.

Figure 8. Organic material feedstock provided for industrial composting facilities during 2018, by county and type of organic material



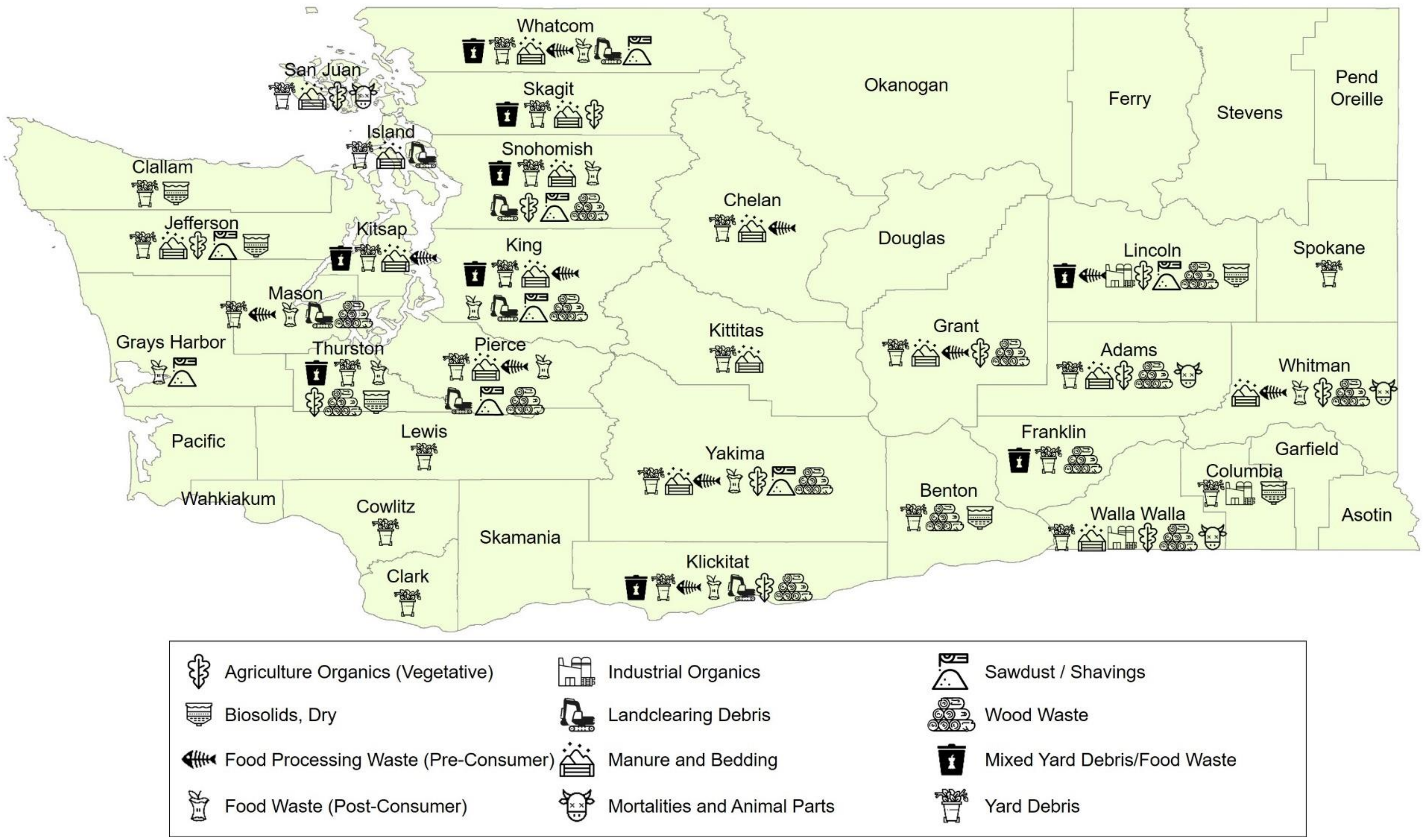
Maps show aggregated data for composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the map. See Appendix 4 for detail.

Feedstock types

Looking more specifically at feedstock types processed by county (Figure 9), yard debris is the most common feedstock as it is being collected in 28 of 30 counties with composting facilities. Also, nine counties with composting facilities have facilities that accept mixed yard debris and food waste: Puget Sound area counties as well as Klickitat, Franklin, and Lincoln. Manure and agricultural organic material (vegetative) are accepted at facilities located in counties with significant agricultural activity in Puget Sound and central and eastern Washington. Similarly, counties with significant forestry operations in the Puget Sound area and southeast Washington process wood waste. A total of 10 counties accept more than five types of feedstock in their facilities: Snohomish, King, Whatcom, Pierce, Yakima, Klickitat, Lincoln, Thurston, Walla Walla, and Whitman

.

Figure 9. Types of organic material processed by industrial composting facilities during 2018, by county



Map shows aggregated data for composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the map. Detail included in Appendix 4.

Figure 10. Organic material feedstocks for industrial composting facilities between 2010 and 2019(p), by type of material

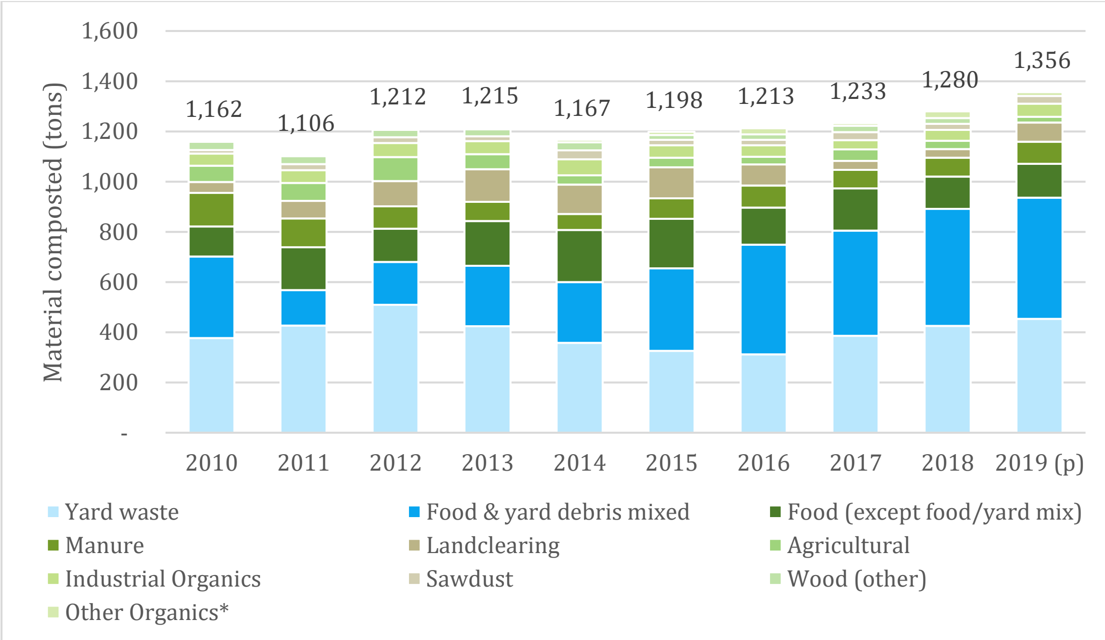


Figure shows aggregated data for composting facilities reporting to Ecology for the years 2010 – 2019. 2019 data are preliminary (p). Data adopted from Ecology (n.d.a., 2019b, 2020b). Other organics include mortalities, animal parts, biosolids, and others not specified.

Trends: volumes and types of feedstock

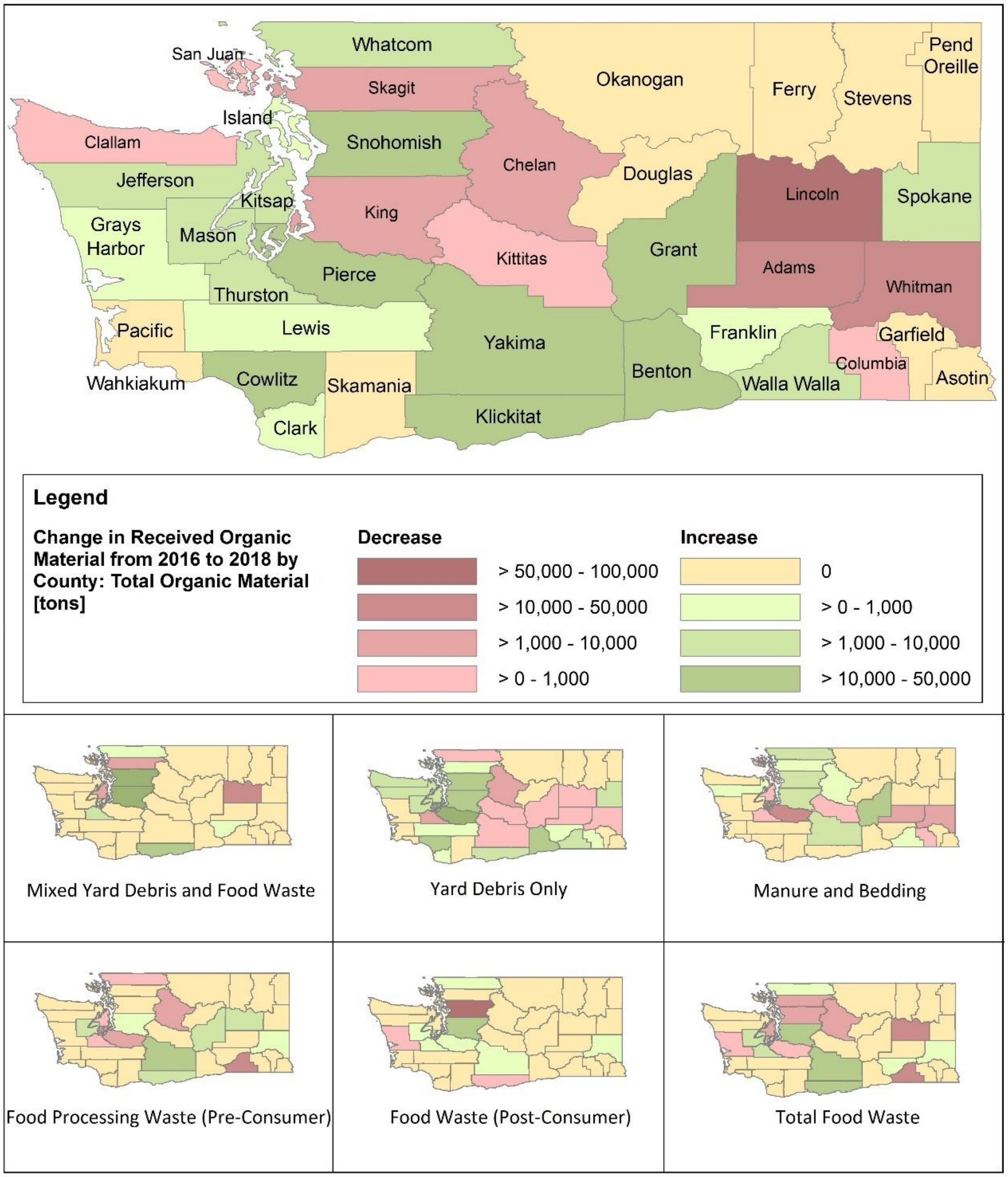
Between 2010 and 2017, more than 9 million cubic yards of organic materials were composted in Washington, with over 1 million tons composted each year (Ecology, n.d.b). The highest volume of material composted occurred in 2017, with 1.32 million tons (Figure 10). Over time, the proportions of various compostable materials have shifted, with yard waste peaking in 2012 at 509,000 tons and declining in subsequent years, with a slight rise in 2017. The proportion of mixed food waste and yard debris has increased over time, becoming the largest proportion of total composted materials in 2016 and 2017 (Ecology, n.d.b).

Between 2016 and 2018, compost facilities in 10 counties reported a decrease in total organic material received, while 18 counties saw an increase (Figure 11). Snohomish, Pierce, Cowlitz, Yakima, Klickitat, Grant, and Benton counties had the largest increases. Lincoln County had the biggest drop, which was a decrease of 51,502 tons, likely linked to changes in how the county's main composting facility – Barr-Tech – reported its composting and biosolids composting operation volumes to Ecology

-

[12]

Figure 11. Change between 2016 and 2018 in the amount of organic material received by industrial composting facilities, by county and type of organic material

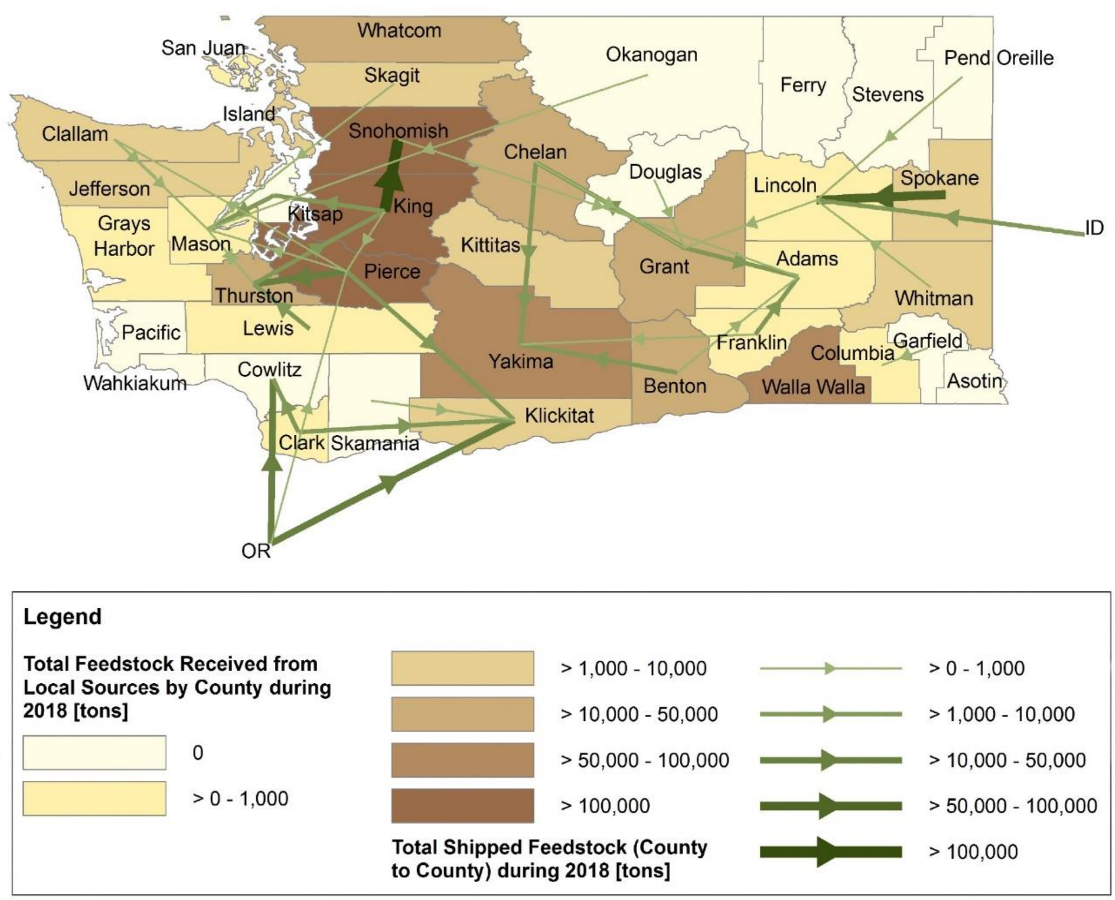


Map shows aggregated data for composting facilities reporting to Ecology for the years 2016 and 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the map. The large apparent decrease in Lincoln County is likely explained by a change in biosolids reporting criteria. Detail included in Appendix 4.

[12] Barr-Tech submits two reports each year (compost and biosolids) and they report compost activity on both. Ecology, from its end, consolidates the information. In Ecology dataset, both yard debris/food amounts from both reports were added, but in 2017 the facility requested to change how its yard/food waste amount was estimated. Also, the 2016 report did not indicate wet or dry biosolids, although after that year, biosolids amount started to be considered as wet. These changes, if applied to 2016 data, would explain 46,993.42 of the 51,502 tons of difference compared to the 2018 report.

In the 2016-2018 period, Snohomish and King counties experienced the highest increase of mixed streams that included yard and food waste (70.1 and 65.5 thousand tons, respectively). Facilities in most counties had increased yard debris feedstock, or experienced limited decreases, especially in Washington's central region. The highest increases occurred in Pierce and Snohomish counties, with 58.3 and 25.2 thousand tons, respectively. Manure and bedding generation generally increased as composting feedstock throughout the state, although Pierce County experienced a significant reduction of 17.4 thousand tons. Food processing feedstock increased in central Washington – especially in Yakima County – while food processing waste did not change significantly during the period throughout the state, except for Walla Walla County, which saw a decrease in this feedstock by 17.1 thousand tons. Overall, food waste (post-consumer) feedstocks increased statewide, with Lincoln and Walla Walla counties as the most salient exceptions.

Figure 12. Flows of organic material transported between counties and organic material received from sources in the same county, by county, in 2018



Map shows aggregated data for composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the map. Counties shaded in brown depict the amount of feedstock processed by facilities from sources within their same counties, while green arrows display the amount of feedstock transported to facilities from other counties and states. Detail included in Appendix 4.

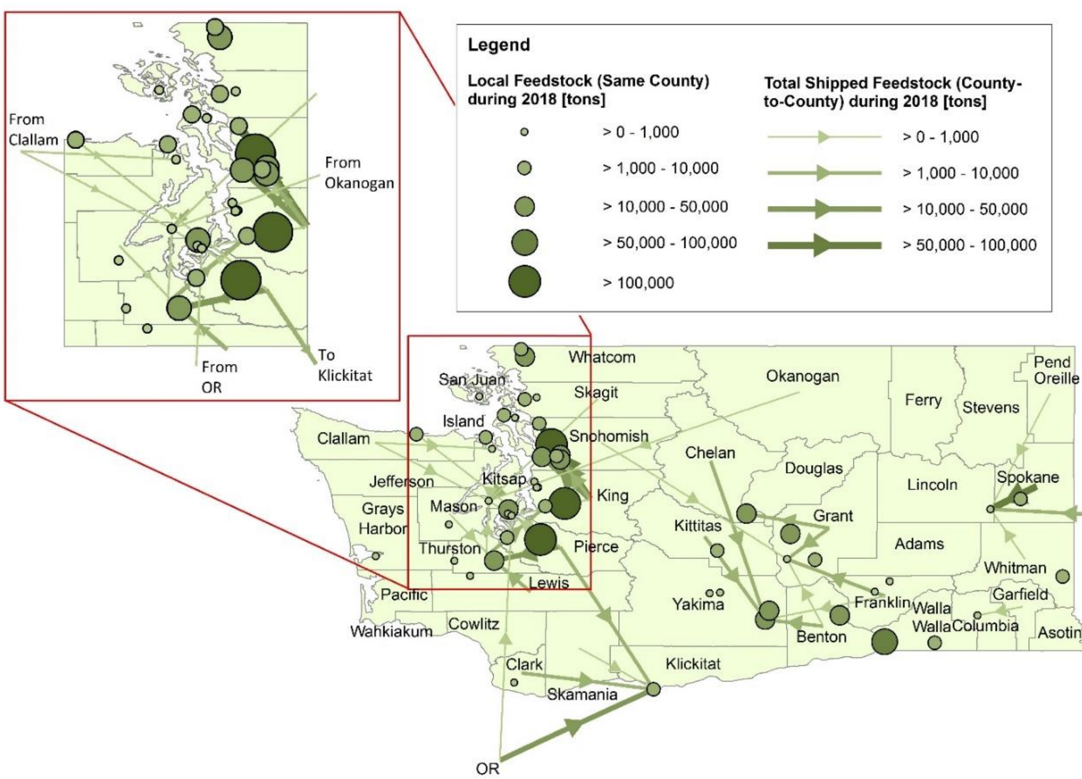
3.3. Feedstock flows

Most organic material processing generally occurs *within* the county where the material is generated (see brown tinting of counties in Figure 12), with highest volumes in Puget Sound counties. The counties of Walla Walla and Yakima are also noteworthy, with high local processing capacity.

Although compost feedstock is usually local, significant quantities are transported between counties and from out of state (Oregon and Idaho). The largest inter-county feedstock transport was from King to Snohomish County (126,347 tons). The second-largest feedstock transfer was from Spokane to Lincoln County (80,207 tons). With these two exceptions, inter-county transport volumes are usually smaller than local sources. In general, counties located in the Puget Sound area engaged in more and larger inter-county feedstock shipments than the rest of the state. Organic material from neighboring Oregon and Idaho came in for processing in Cowlitz, Klickitat, and Lincoln counties.

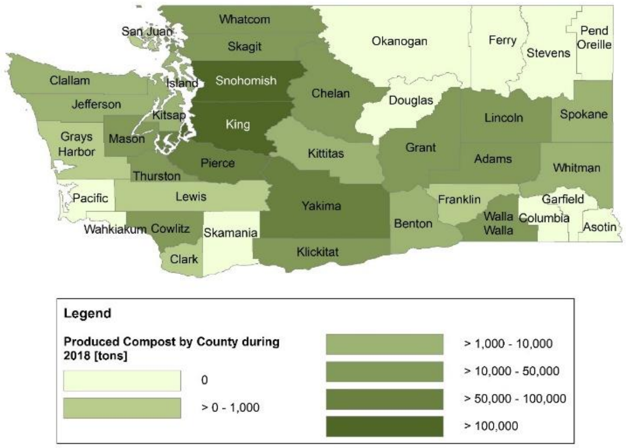
Looking at feedstock flows to individual facilities (Figure 13: arrows represent out-of-county sources and dots represent in-county sources), the same overall flow pattern is seen. Four facilities located in Klickitat, Yakima, Grant, and Lincoln, stand out because of their significant imports from three or more counties/states.

Figure 13. Flows of material transported from counties to industrial composting facilities in different counties (arrows) and volume of organic material received from within counties (dots) in 2018



Map shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the map. Green arrows display the amount of feedstock transported to facilities from other counties and states, while dot sizes display the amount of feedstock provisioned from counties where facilities are located. Detail included in Appendix 4

Figure 14. Volume of compost produced at industrial composting facilities in 2018, by county



Map shows aggregated data for composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the map. Detail included in Appendix

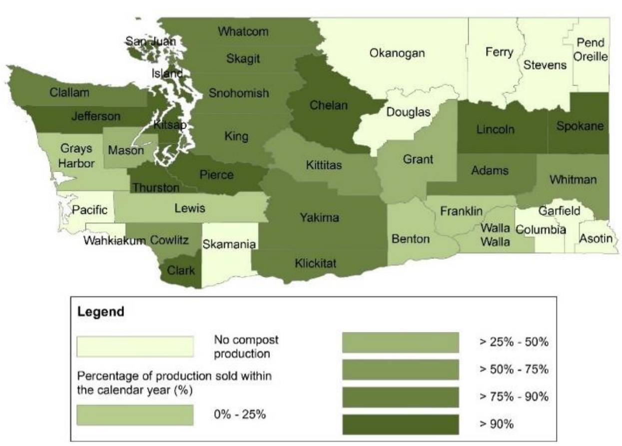
3.4. End-Uses and Markets

Washington's ten highest-volume compost facilities, all but two of which are located in western counties, contribute 80% of the state's produced compost. In 2018, Snohomish and King counties each produced 100,000 or more tons of compost (Figure 14). Eleven counties – characterized by small populations - do not have composting facilities operating under solid waste permits or that are required to report annual activities to Ecology, as previously noted.

To approximate compost product demand, compost amount sold is compared with its production during the same year at each facility aggregated by county (

Figure 15). At least 75% of the compost products (on an aggregated basis) were sold in most counties with facilities producing compost. Furthermore, facilities located in eight counties sold more than 90% of their aggregated production: Pierce, Thurston, Lincoln, Adams, Chelan, Jefferson, Kitsap, and Clark.

Figure 15. Reported percentage of compost production sold during the same calendar year of its production, by county in 2018



Map shows aggregated data for composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology 2019b. Facilities processing biosolids associated with wastewater treatment plants are not included in the map.

3.5. Comparison with 2019 preliminary data

The total 2019 volume of organic material feedstock processed by compost facilities reporting to Ecology was 1,356,290 tons, according to preliminary data (Table 2) provided by the agency.[13] This represents an increase of 75,874.6 tons of feedstock relative to 2018 volumes (6.6%), which continues the upward trend observed since 2014 (Figure 11 above). The 2018 to 2019 increase was primarily driven by an additional 27,353.4 tons of yard debris, 20,246.6 tons of food processing waste, and 17,605.5 tons of land clearing debris.

Table 2. Volumes of organic material feedstocks processed by compost facilities reporting to Ecology during 2019, in tons.

Preliminary information provided by the agency.

Feedstock	Compost Facilities (Permitted)*	Compost Facilities (Permit Exempt)*	Biosolids Management**	Totals	2018-2019 change
Agricultural organics	21,270.7	7.4	2,149.0	23,427.1	(9,535.7)
Biosolids	5,963.5		4,547.5	10,511.0	4,227.8
Food processing waste	84,278.4			84,278.4	20,246.6
Food waste post-consumer	49,969.0	163.9	238.1	50,370.9	(13,348.3)
Industrial organics	52,235.8			52,235.8	9,362.5
Land clearing debris	75,866.1			75,866.1	41,234.0
Manure with bedding	43,459.6	41,004.6	3,620.0	88,084.2	12,308.2
Mortalities	2,399.0	10.5		2,409.5	(17,836.4)
Sawdust and shavings	6,796.4	11,470.0	12,740.7	31,007.0	6,771.5
Wood waste	8,641.0	19.4		8,660.4	(14,968.2)
Mixed paper	36.8		8.8	45.5	3.4
Yard Debris and Food Scraps (mixed)	482,938.0			482,938.0	16,937.4
Yard debris	414,249.4	19,122.2	19,965.9	453,337.5	27,353.4
Other organics	189.0		1,590.0	1,779.0	1,778.7
Total	1,248,292.5	71,798.0	44,859.9	1,364,950.4	84,534.9

Permitted and exempt facilities reporting under WAC 173-350-220,

* Permitted facilities reporting under WAC 173-308. Source: Ecology (2020b).

[13] Unpublished data from Ecology, December 2020

Chapter 4: Current status of other organic material management facilities in Washington

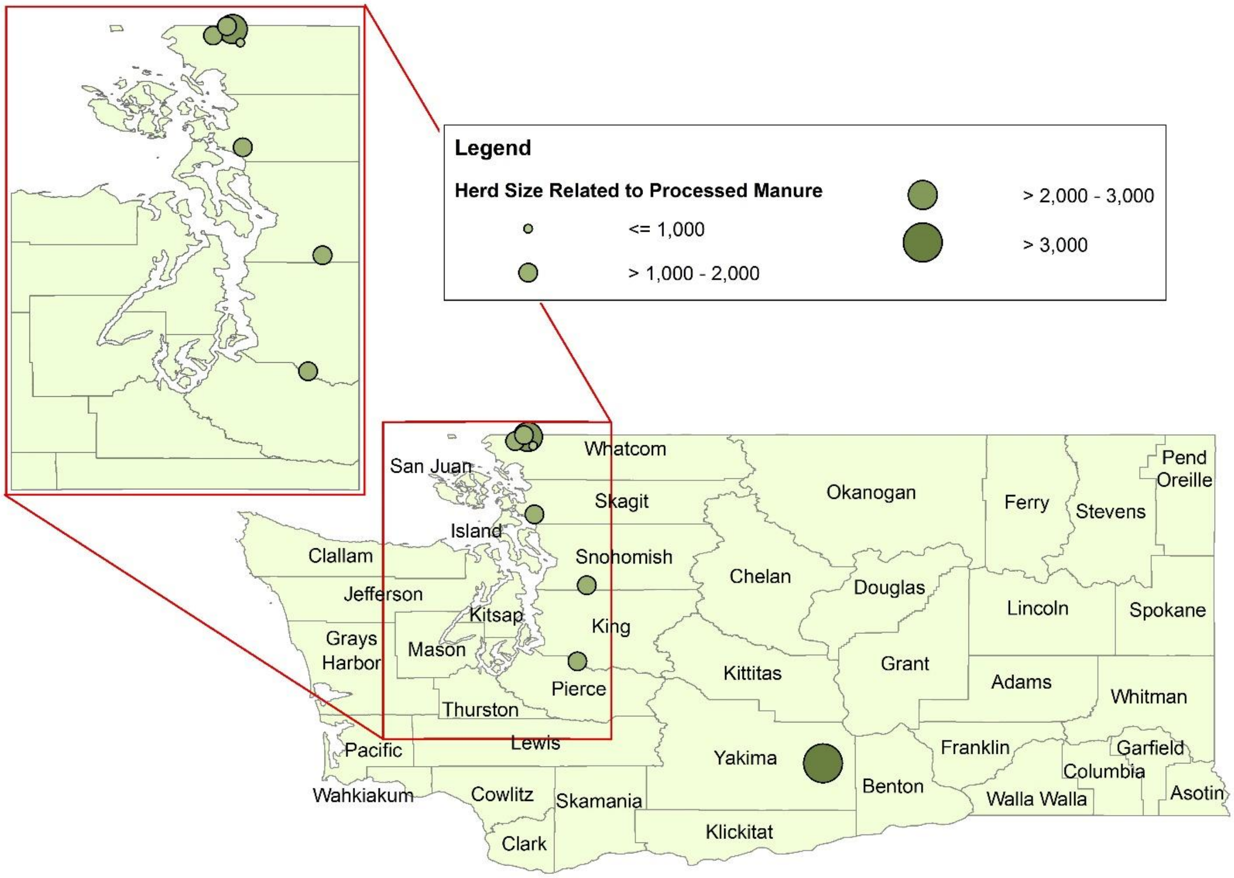
In addition to composting, anaerobic digestion, land application, energy recovery and incineration, and landfill disposal are other methods for managing organic materials in Washington. Current status, end-use markets, and trends of these methods are described in this chapter. Barriers and challenges are summarized later in chapter 5.

4.1. Anaerobic Digestion

The development of Washington's bioenergy industry was originally fostered through WSU and Ecology collaborative partnership. In 2005, the collaborative inventoried the bioenergy potential of a range of organic materials, including manure, food waste, and agricultural waste (Frear et al., 2005). This early work led to the development of the industry and its associated regulation in the following years. In June 2008, natural gas prices peaked. Then the prices declined dramatically and finally got as low as pre-1990 prices by 2015. Since then, the bioenergy industry has stagnated as incentives, and price variation in energy markets caused uncertainty.

Most of Washington's currently operating anaerobic digesters (33) are located at wastewater treatment plants and manage solids from the sewage, generating biogas.

Figure 16. Dairy operations-based anaerobic digesters that operated during 2019 in Washington



Map based on data and adopted from EPA (2020j) and Ecology (n.d.d)

Two of the largest wastewater treatment plant digesters are located in King county: West Point and South Plant. These two plants account for nearly half of the county's Wastewater Treatment Division energy use (around 400,000 MMBtu) (King County Wastewater Services, 2020). Other notable examples are the Chambers Creek Regional Wastewater Treatment Plant in Tacoma and LOTT in Olympia (Newcomb, 2016; WSDA, 2011).

Nine other anaerobic digesters (Figure 16) are farm-based and digest manure and slurries from dairy operations as their primary feedstock (most co-digest food processing waste) (ABC, 2020). These projects are mostly located in Whatcom county, although the largest facility – G DeRuyter and Sons Dairy Digester (Table 3) – is located in Yakima County. These two counties – Whatcom and Yakima - have most of the state's dairy production (see Appendix 5)(Ecology, n.d.c).

All farm-based digesters in the state initiated their operations in 2015 or earlier (Table 3). Several of these facilities have undergone upgrades and fixes over time – roofs collapsed, for example, on two dairy digesters (JLARC, 2020). The predominant operational model is the co-digestion of manure slurries with food-processing waste (WSDA, 2011). The financial viability of digesters is supported by existing tax

Table 3. Dairy operations-based anaerobic digesters in Washington in 2020

Facility	City (County)	Start Year	Dairy Size (heads)	Biogas End Use
Blok's Evergreen Dairy Inc.	Lynden (Whatcom)	2015	NA	NA
Edaleen Cow Power, LLC Digester	Lynden (Whatcom)	2012	2,500	Electricity
Farm Power Lynden Digester [i]	Lynden (Whatcom)	2010	2,000	Electricity
Farm Power Rexville Digester	Mount Vernon (Skagit)	2009	1,500	Electricity
G DeRuyter and Sons Dairy Digester[ii]	Outlook (Yakima)	2006	4,000	RNG (3)
Qualco Energy Digester	Monroe (Snohomish)	2008	2,000	Electricity
Rainier Biogas Digester	Enumclaw (King)	2012	1,500	Electricity
Van Dyk Dairy Digester	Lynden (Whatcom)	2011	800	Electricity
Vander Haak Dairy Digester	Lynden (Whatcom)	2004	1,500	Electricity

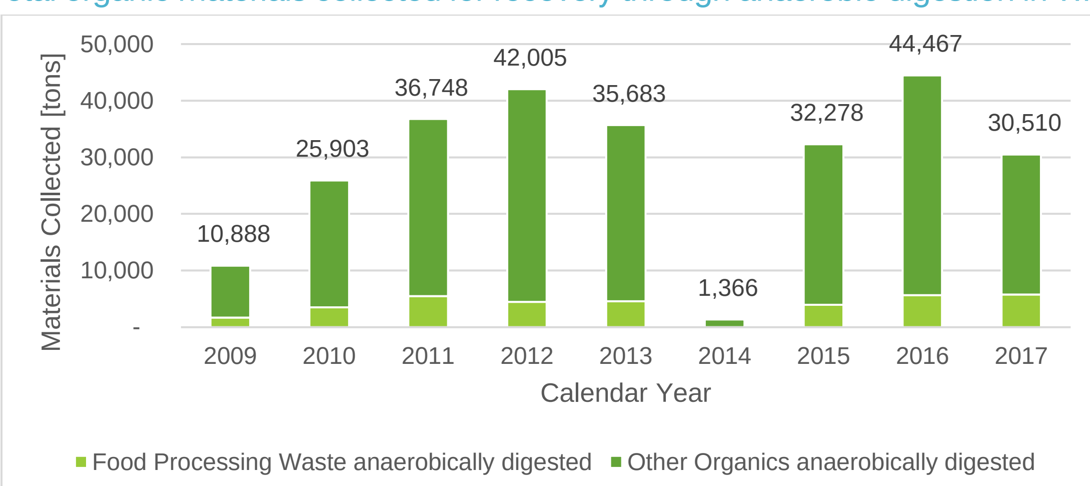
Notes:. (i) Currently shut down (ii) Only facility in Washington producing renewable natural gas for CA LCFS. Only facility processing manure-only feedstock due to its lower LCFS carbon scoring. *Source: Based on EPA (2020j) and C. Frear, personal communication (2021, March 11)*

preferences in Washington (sales and use tax exemptions, as established per 82.08.900 and 82.12.900 RCW) along with markets associated with RINS and California and Oregon Low Carbon Fuel Standard (LCFS). There were no anaerobic digesters constructed prior to the enactment of tax preferences by the Washington Legislature in 2001 (JLARC, 2020).

Most of the westside facilities practice co-digestion, while the Yakima facility digests only manure. This facility (G DeRuyter and Sons) produces RNG, and it is incentivized through CA LCFS and thus receives higher carbon scoring by not practicing co-digestion. All facilities on the westside produce electricity but will soon need to find other solutions like e-LCFS in the future due to likely lower power purchase agreements (PPA) pricing (C. Frear, personal communication, March 11, 2021).

The amount of organic material processed by anaerobic digestion facilities in Washington has fluctuated but has not significantly increased since the start-up period 2009 through 2013 (Figure 17).

Figure 17. Total organic materials collected for recovery through anaerobic digestion in WA, 2009-2017



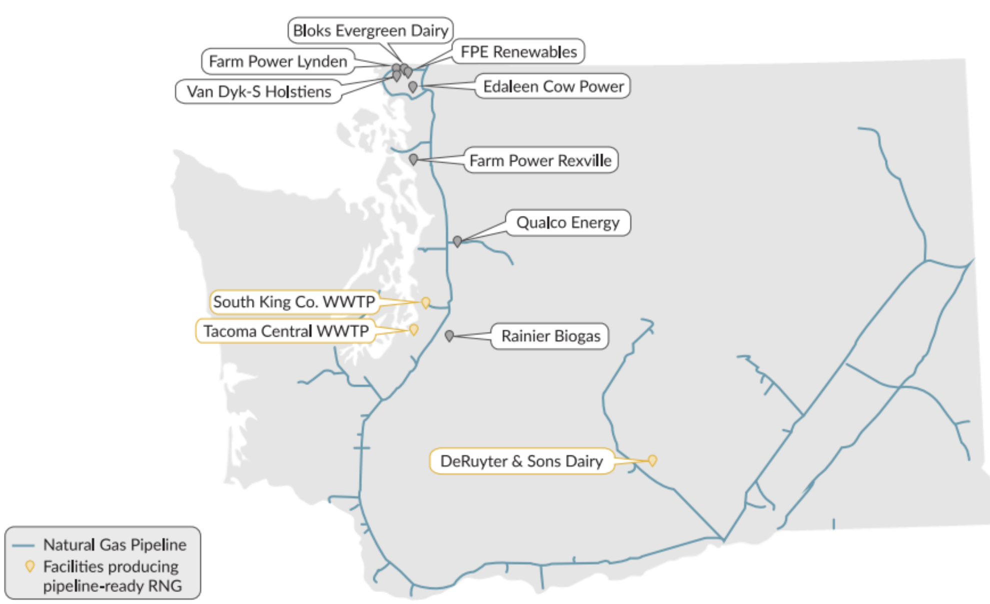
Notes: (1) Food processing waste anaerobically digested: includes pre-consumer food processing waste and pre-consumer food waste that contains animal by-product that is source separated at the facility. (2) Anaerobic digesters began reporting in 2009. (3) There is a reporting gap in 2014 for unknown reasons. (4) Other Organics anaerobically digested: includes livestock manure, bedding, and other non-food materials digested. Reported in gallons as a slurry. *Source: Based on Ecology (n.d.d)*

Washington's anaerobic digestion industry is expanding after stalling for years. An ongoing project in Snohomish County will increase Qualco Energy's capacity by incorporating 400 dairy cows' manure into the existing digester. An upcoming partnership with the Snohomish County Public Utility District could further expand the capacity (Sanders, J., 2020). The Vander Haak facility has a partnership with Lautenbach to source food waste separated by a de-packager.

Western Washington facilities are also considering their participation in e-LCFS for future electricity sales as an alternative to their current model based on power purchase agreements (PPA). The G DeRuyter and Sons facility in Yakima completed its conversion to RNG, and additional projects consider the model in Eastern Washington as natural gas pipeline infrastructure exists (Figure 18). The Washington State Department of Commerce recently granted four dairy digester clean energy projects under the Dairy Digester Enhancement Program (Commerce, 2020).

- G DeRuyter & Sons: Conversion from flush-to-flush flume to improve the facility capacity, efficiency, and production quality.
- Edaleen Cow Power: Acquisition of equipment and infrastructure for completing a new long-term offtake agreement destined to power electric vehicles.
- FPE Renewables: Purchase and installation of a de-packaging system for production and delivery of a new slurry feedstock stream for FPE and other digesters in Washington.
- Organix, Inc.: Comprehensive pilot study on potential benefits of processing anaerobic digester effluent using the BioFiltro BIDA System.

Figure 18. Anaerobic digesters operating in Washington, located close to the natural gas pipeline highlighting the three with existing RNG production



Source: JLARC (2020)

Figure 19. Land application sites operating under solid waste management permits in Washington in 2017

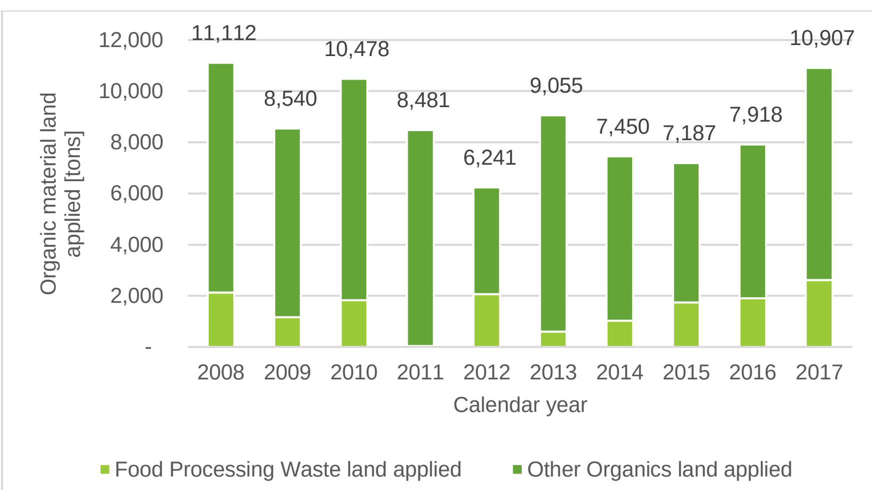
Map shows permitted land application sites reporting to Ecology for the year 2018. Data adopted from Ecology (n.d.b)

4.2. Land Application

A total of 15 land application sites (Figure 19, see detail in Appendix 6) hold solid waste management permits in the state (Ecology, n.d.d). These sites are located in the state's central and southern regions, especially in Benton and Grant counties.

From 2008 through 2017, the amount of organic material managed through land application in Washington was within the range of 6,000 to 11,000 tons per year (Figure 20). This stream contains mostly organic material from agriculture activities. Food processing waste is also land applied at levels up to 2,618 tons per year. These totals do not include land application of manure and bedding, crop residue, on-farm vegetative waste, compost, digestate, which do not require land application permits if they are managed according to regulations.

Figure 20. Total organic materials applied to land in Washington, 2008-2017



Land applied food processing waste includes wastes such as cranberry waste; excludes potato dirt. "Other Organics land applied" include agricultural wastes and exclude potato dirt. Graph based on data from Ecology (n.d.d).

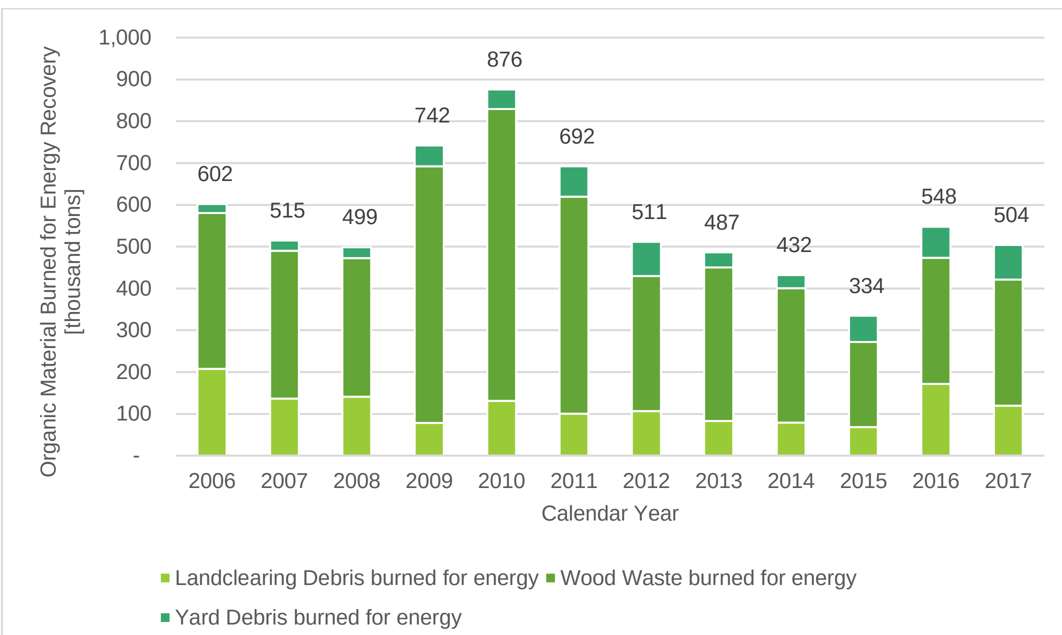
4.3. Energy Recovery

Energy recovery includes waste management methods that generate electricity, heating, and fuels through the combustion of organic materials.[14] State regulations allow generators of wood waste, wood-derived fuel, wastewater treatment sludge from wood pulp, and paper to manage their waste by burning it for energy recovery, and usually do not require a permit.[15] Solid Waste Management permits are required, however, for incineration/Waste-to-Energy and energy recovery processing municipal solid waste. Combustion of organic material is generally prohibited in urban areas (WAC 173-350-040).

Energy recovery

Organic materials burned for energy recovery in Washington (Figure 21) between 2006 and 2017 ranged from 334,000 to 876,000 tons per year. These totals include management of organic waste received from landscaping operations, construction and demolition (C&D) material recovery facilities (MRFs), papermills, and other organic material generators in the state.[16] Combusted organic materials during this period contain mostly wood waste (which shows the most variation), with lower amounts of land clearing and yard debris (which remain more constant over this period).

Figure 21. Total organic materials burned for energy recovery in Washington, years 2006-2017



Graph includes source-separated organic materials reported as recovered and sent to facilities that burn the material for energy generation. Does not include solid waste incineration/Waste-to-energy, energy recovery waste to fuel or conversion technologies such as anaerobic digestion and pyrolysis. Land clearing debris include mixed woody debris including stumps, brush, and limbs. Wood Waste burned for energy includes wood from construction or demolition, mill waste, and sawdust. Data adopted from Ecology (n.d.d).

[14] While anaerobic digestion is also an energy recovery alternative, it is usually analyzed separately because it also generates digestate that can be used as a fertilizer.
[15] Combustion of organic materials is generally prohibited in urban areas.
[16] Incineration, pyrolysis/gasification, and anaerobic digestion are not considered in these figures.

Table 4 Facilities with hog fuel boilers regulated by Ecology's Air Quality and Solid Waste Management programs, 2021

Avista	Pt Townsend Paper
Boise Cascade Wood Products, LLC Kettle Falls Lumber	SDS Lumber Company
COSMO Specialty Fibers, Inc.	Sierra Pacific Industries
Enwave	Sierra Pacific Industries - Centralia Division
Guy Bennett Lumber	Sierra Pacific Industries - Cogeneration
Hampton Lumber Mills Washington Inc	Sierra Pacific Industries - Shelton
Hampton Lumber Mills/Cowlitz Division - Morton	Vaagen Brothers Lumber Inc
Hampton Lumber Mills/Cowlitz Division - Randle	WestRock Longview, LLC
McKinley Paper Company	WestRock Tacoma Mill
Nippon Dynawave Packaging Co.	Weyerhaeuser Raymond
Packaging Corporation of Am – Boise Cascade Wallula	

A total of 22 facilities in Washington operate hog fuel boilers regulated by Ecology's Air Quality and Solid Waste Management programs (Table 4). According to Ecology,[17] facilities with smaller capacity operating hog fuel boilers are likely to be regulated by local clean air agencies. Appendix 7 includes a list of 31 additional facilities that operated a hog fuel boiler in 2003 and that remain in commercial operations as of 2021, although no information about the equipment is publicly available.

Biochar Production

Biochar is a solid amendment that is produced through the combustion of organic matter in presence of limited oxygen. It can be used directly or blended with other soil amendments to improve soil health, sequestering carbon, and improving soil moisture (Pacific Northwest Biochar Atlas, n.d.a). Certain facilities producing biochar are exempted from solid waste handling permits. Per WAC 173-350-240, exempted facilities include those that only handle wood waste or wood pulp or paper manufacturing wastewater sludge. Facilities burning up to 12 tons of organic solid waste are also exempted. According to the Pacific Northwest Biochar Atlas (n.d.b), biochar producers operating in Washington include six facilities (Table 5).

Some industrial compost facilities in Washington are currently analyzing the potential for incorporation of biochar in their products as a complementary soil amendment for the improvement of soil health and crop yield increase (Amonette et al., 2021). One supplier – Short's Family Farm in Port Townsend- has already started to combine some of their

Table 5 Biochar facilities in Washington State, 2015

Biocharm Farms	Karr Group
Biochar Supreme	Miller Soils LLC (& Colorado)
Ecotrac Organics	Pacific Northwest Biochar

[17] Personal communication with staff of the Industrial Section of Ecology's Solid Waste Management Program.

compost blends with biochar produced from forest and untreated wood products (Short's Family Farm, n.d.).

Incineration and biofuel manufacturing

Two facilities hold solid waste permits for incineration and waste-to-energy: the Spokane Regional Waste-To-Energy Facility in Spokane County and the BioFuels Washington Energy Facility in Pierce County. Two additional waste-to-energy facilities operate in the state but are exempted from solid waste handling permits because of their feedstock types: Ponderay Newsprint Co. (Usk, Pend Oreille) and Inland Empire Paper Co. (Spokane, Spokane County) (Ecology, n.d.d). As per WAC 173-350-240 Table 240-A, facilities combusting wood waste, wood-derived fuel (e.g., hog fuel), or wastewater treatment sludge from manufacture of wood pulp or paper are not required to hold a solid waste permit.

The Spokane Regional Waste-to-Energy Facility is the largest such facility in the state and, in 2017, processed a total of 251,879 tons of medical, industrial, and municipal waste. In 2015, the facility's organic feedstock totaled approximately 60%, including paper packaging (8.1%), paper products (9.5%), organics (32.3%), and wood wastes (10.0%). (Ecology, 2018a). The material is almost exclusively sourced from

Spokane County (99.7%) (Ecology, n.d.d).

4.4. Landfill Disposal

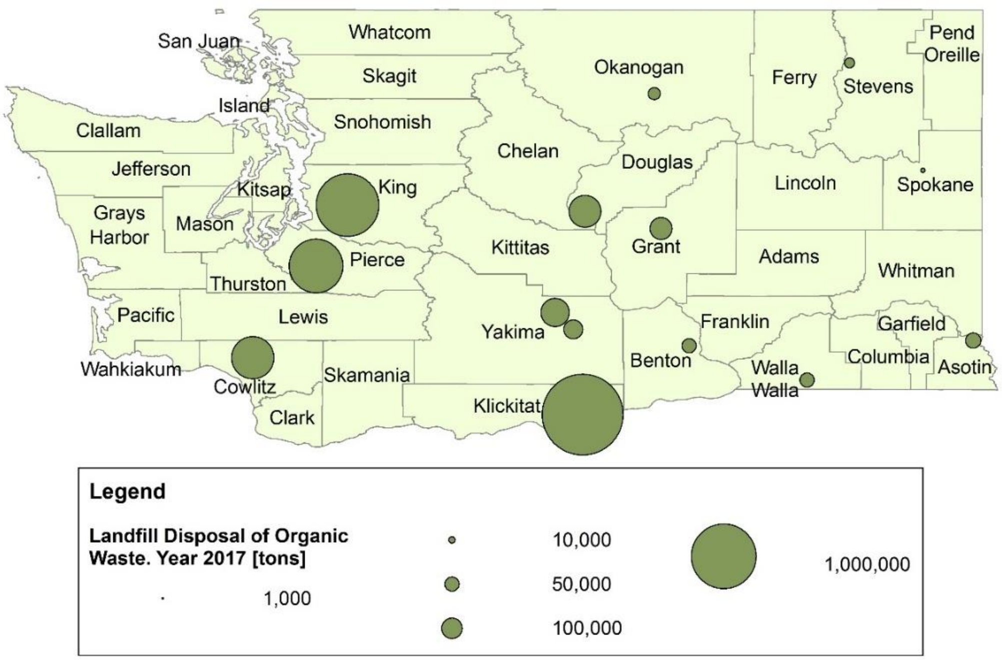
Landfill disposal with and without energy recovery is the least preferred organic waste management method in the state's waste hierarchy (see Figure 22, see detail in Appendix 8).. Landfill Gas-to-Energy operations are part of the operations of six landfills in Washington (ABC, 2020). These gas collection systems roughly capture 60 to 90% of methane emissions during the waste anaerobic degradation phase (EPA, 2020k).

Amounts of organic waste sent to landfills:
Fourteen landfills (Figure 22) in the state received a total of 4.4 million tons of waste streams containing organic waste during 2017 (Ecology, n.d.d)[18]. The Roosevelt Regional Landfill – located in Klickitat County - received the largest amount (1.5 million tons). Other large facilities are Cedar Hills Landfill in King County and LRI Landfill in Pierce County.

Generation of organic waste sent to landfills:
Highly populated and industrialized areas of the state generate the largest amounts of waste streams containing organic materials sent to landfills (Figure 23). Snohomish, King, and Pierce counties account for 47% of the state's total generation of these waste streams. Other large-generating source counties include Whatcom, Skagit, and Kitsap (Northwest region), Thurston, Cowlitz, and Clark (Southwest region), Yakima and Benton (Central region), and Grant, Franklin, and Spokane (Eastern region).

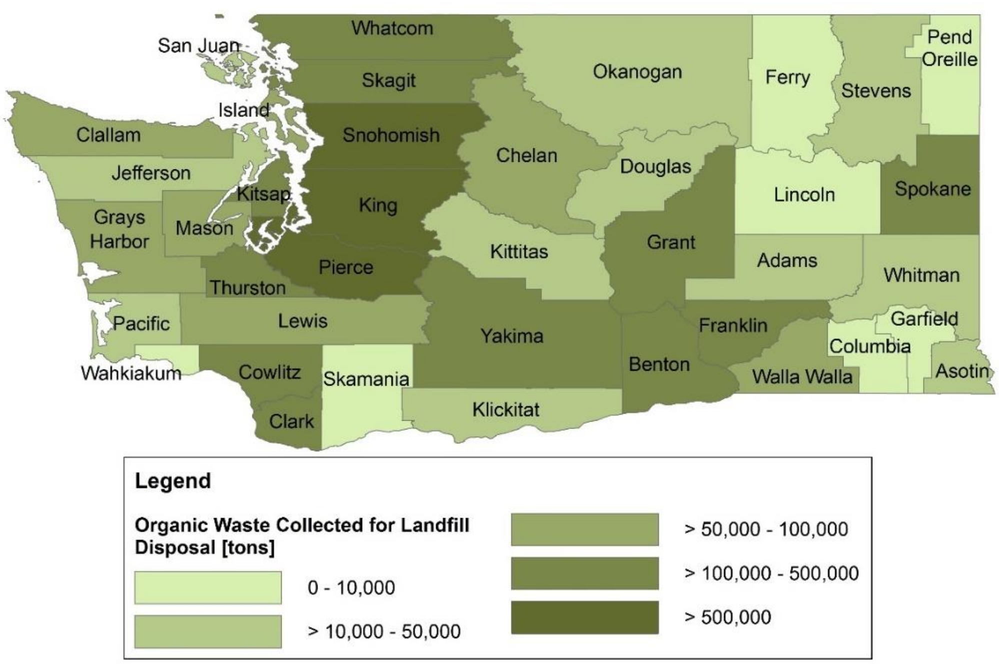
[18] Includes municipal solid waste (MSW), industrial waste, wood waste, yard debris, sewage sludge, food processing, land clearing debris, and mortalities and other animal parts.

.Figure 22. Location of landfills in Washington receiving solid waste streams containing organics and their relative organics disposal volumes, in 2017



Data is from and adapted from Ecology (n.d.d). Legend volumes and dots on map are shown in rough proportion to the size of disposal amounts. Inert waste and limited-purpose landfills are not included. Total volumes include municipal solid waste, industrial waste, wood waste, yard debris, sewage sludge, food processing waste (pre-consumer), land clearing debris, and mortalities and other animal parts. Volumes include out-of-state waste from British Columbia, Oregon, Idaho, Alaska, and California (409,479 tons). Washington ccounties and cities shipped additional 1.4 million tons of waste to three Oregon landfills : Columbia Ridge, Finley Buttes, and WASCO MSW.

Figure 23. Generation of solid waste streams containing organics by county. Year 2017



Data for map is adapted from Ecology (n.d.d). Includes the following waste streams: Municipal solid waste, Industrial waste, Wood waste, Yard debris, Sewage sludge, Food processing waste (pre-consumer), Land clearing debris, and Mortalities and other animal parts. Counties and cities in Washington transported additional 1.4 million tons of waste to three landfills located in Oregon: Columbia Ridge, Finley Buttes, and WASCO MSW landfills.

Chapter 5: Barriers and Challenges for Improving the Management of Organic Materials

The organic waste management system in Washington has had many successes. There is room for improvement, however, as approximately 1,308,018 tons (28.5%)) of the disposal load is organic material (Ecology, 2018), with the associated environmental and financial burdens. In this study, we explore the barriers and challenges to the expansion of and improvement of organics management.

This analysis is based on a review of the literature and interviews[19] with 61 agency, industry, and academic experts. Barriers and challenges are grouped as follows:

- Logistics
- Financial burden and risk
- Regulatory challenges
- Operational issues
- Contamination
- Demand and end-markets
- Capacity and knowledge
- Coordination and Competition.

5.1. Logistics

Organic residues are costly to transport and are challenging materials to manage, especially when containing highly putrescible loads such as food scraps. The potential for odor issues can cause siting issues. Furthermore, the material

[19] To allow for candid interviews, we do not provide specific citations for statements drawn from interviews in this and the next chapter.

can start to degrade while still in the collection containers causing odors, liquid issues, and attraction of pests. Finally, apple maggot quarantine restrictions have led to further logistical constraints.

Transportation costs

The transportation of organic waste is expensive, primarily due to its weight (due to moisture) and the location of facilities in industrial or other areas distant from source communities. Lower land and labor costs in eastern Washington, however, can in some cases compensate for increased transportation costs. For example, a new facility (PacifiClean) was built in Quincy in 2015, specifically to handle roughly two-thirds of Seattle's collected organic waste (Courtney, 2016). It closed soon after it opened, however, due to the challenge posed by the apple maggot issue, related to transfer of material through and to pest-free areas of the state (Probert, 2014, Pratt, 2015).

Land availability and siting issues

Large-scale industrial organic management facilities require significant physical space to handle materials, manage emissions, reduce odors, and avoid noise disturbance. In particular, facilities operating near to populous areas also require high levels of investment to incorporate BMPs, possibly even enclosing parts of the process and scrubbing the emissions. Facilities constructed in less dense areas can usually realize lower land, labor and KPI-related costs, but by being located farther from municipal feedstock sources they face higher transportations costs. Facilities in urbanized counties are often located in industrial areas to reduce communities' exposure to emissions and vector attraction.

Siting new facilities or expanding operations, especially for including complex-handling materials - like food waste - can be difficult. Both composting facilities and digesters see their expansion limited because of available land constraints, although the former also must address potential odor concerns and the latter may find opposition due to concerns about operational risks due to spills and explosions. One solution that has been promoted by waste companies is to co-locate compost and other organic waste management facilities at landfills, transfer stations, and similar locations, which could ease permitting issues and make use of existing space (Karidis, 2020).

Zoning gap

The lack of clearly defined zoning imposes a barrier to the development of new facilities by not proactively informing about land availability for organic management operations.

Zoning for organic waste management facilities varies widely among local governments, both at the county and city levels. Certain local governments do not have land use definitions specific to composting operations, which increases uncertainty for project developers by requiring public officials' interpretation. The United States Composting Council (USCC) found that the lack of zoning is one of the most significant barriers to construction of composting facilities. The council is developing a model zoning template for incorporating into local ordinances (BioCycle, 2020a).

Apple maggot impacted fruit. *Photo: WA Department of Agriculture*

Apple maggot quarantine restrictions

Since 2015, Washington has posed limitations to movement of untreated green waste (yard debris and agricultural organics) through or to apple maggot quarantine areas in order to protect the state's important apple crop production (Sansford et al., 2016). Appendix 9 includes a map of quarantined areas in the state.

Specifically, the WSDA is authorized to issue special permits for transportation of green waste if operations meet moisture and one of these time-temperature criteria (Ecology, 2018b):

- Materials are maintained at 55°C for two weeks, 65°C for one week, or 60°C for one week in an enclosed system.
- Materials are treated at 75°C for four hours, 80°C for two hours, or 90°C for one hour.

The needed compost-like or steam treatment can increase operational costs significantly and cut off the high supply of organic materials collected in highly dense municipal areas west of the Cascades to the agricultural operations on the eastside. To date, one special permit has been granted by the WSDA to Okanogan County Public Works for transporting treated green waste between the county's quarantined and pest-free areas. Additional permits have been issued for transporting municipal solid waste that includes green waste. Waste Management, for example, has such a permit to transport municipal solid waste to their landfill in Douglas County (Mehaffey, 2017).

5.2. Financial Burden and Risk

The construction of composting and anaerobic digestion facilities is capital intensive as business models usually consider long paybacks. Facilities operate under tight margins. Feedstock and sales can be uncertain, as organic materials are part of public programs which evolve and also are subject to a highly seasonal and elusive compost market.

Capital investment and payback

Critical determinants of the viability of capital projects in organic management include financial burden and debt service. Capital costs for siting new or expanding existing facilities usually require governmental support, as these parties also determine most or a significant proportion of feedstock flow (See sidebox for innovative approach in Manitoba).

Under Washington's regulations, organic management facilities are responsible for negotiating fees for their services with commercial and residential waste haulers. Extensive service areas are designated by the Washington State Utilities and Transportation Commission (UTC) and through contracts with cities and towns, which diminish processors' negotiation capacity with haulers. Further, small-scale anaerobic digesters and in-vessel composting have even scarcer funding availability as these methods are still perceived as uncertain by investors (Commerce, 2020; Streeter and Platt, 2017).

Reliance on external players

Organic waste management facilities need a continuous procurement of organic materials thus, they are dependent on the volumes and characteristics of the streams they receive from partnering organizations – especially governments (Commerce, 2020). Contamination also has a significant impact on operations and product quality, and its reduction requires coordinated efforts with haulers and governments. This dependency on actions by external actors limits processors to only a few solutions such as "accept/reject" policies and the acquisition of screening and similar equipment.

Addressing organics management goals through green bonds

In February 2021, Canada's province of Manitoba launched a $1-million Organics Green Impact Bond. The issuance aims to support projects that help to divert organic waste from landfills, create green jobs, and reduce greenhouse gases.

Green bonds are an innovative approach for raising funds from the private sector. These instruments require a service provider to meet agreed-upon outcomes for organic waste diversion. In parallel, investors provide up-front funding while a third-party evaluator determines whether the outcomes are met and the return on investment to be paid by the issuer.

Anaerobic digester business models

Business models for anaerobic digesters currently rely heavily on government incentives related to greenhouse gas emission reductions. Business models for anaerobic digesters include:

- Electrical generation through power purchase agreements (PPA): This model relies on the generation of electricity from biogas as part of power purchase agreements (PPAs) and it is the predominant approach among Washington digesters. At present, prices received by facilities have decreased significantly because of gas production from fracking. Also, the development of more-competitive solar and wind projects has allowed the state to meet electrical portfolio targets thus de-emphasizing the interest of utilities in new anaerobic digestion projects. Co-digestion at wastewater treatment facilities (WWTF) and farms could improve revenue plans via extra tipping fees and sales of biogas and electricity, although such operations still struggle to maintain a positive cash flow or to build new projects with the low electrical pricing of traditional PPAs.

- Electrical generation through e-LCFS: This model is based on the generation of electricity from biogas as part of low carbon fuel standard programs (LCFS), currently run by other states such as California and Oregon. Facilities sell the electricity as a fuel for electric vehicles in those states and get confirmed for LCFS credits. The scheme requires generators to meet states' requirements and engage local utilities that would otherwise not be interested because they receive no direct benefit. Prices received can be higher than those in traditional PPAs. The future possibility that the federal renewable identification number (RIN) program might start to include electric vehicles powered from renewable sources (eRIN) as an add-on to the state credits would benefit this revenue model (EESI, 2019).
- Renewable natural gas (RNG) production: This business model relies on the processing of biogas so that it is purified and compressed enough to enter pipeline infrastructure as renewable natural gas. The model can be profitable with both state LCFS and federal RIN credit pricing, available on top of the thermal value for natural gas. As capital and operating costs for these projects are relatively high, this model works best with larger-scale facilities such as concentrated animal feeding operations (CAFOs) and major wastewater treatment facilities (WWTFs). Financial feasibility of this model heavily relies on proximity to pipeline infrastructure. The price structure of renewable identification numbers (RINs), associated with the Washington's Renewable Portfolio Standards (RPS) requirements, currently disincentivizes the inclusion of food scraps with other organic materials (CalRecycle, 2020), thus co-digestion projects. This is because federal standards categorize fuels produced from streams that include food scraps as advanced biofuel (D5). D5 biofuels. This fuel category receives lower payments than cellulosic-derived fuels (D3), which are obtained from digesting only manure and wastewater treatment sludges. Significant variability of the price of RINs also imposes an additional layer of uncertainty for developers of anaerobic digesters (EPA, 2020).

Municipalities interested in exploring biogas and RNG projects among their waste management options can consider partnering with nearby communities to generate scale for such projects., Impacts on existing organic management operations, products, and associated markets should be considered.

Landfill tipping fees, as competition

Landfill disposal is a form of competition for facilities managing organic materials, as commercial customers and local governments can limit or opt-out of services. Landfill tipping fees are highly variable throughout the state, with prices ranging from $28.80/ton in Grant County to as high as $400 in Orcas Island (see Appendix 10). Low landfill tipping fees discourage investment in organic management facilities, as economic factors strongly drive most generators (Brady, 2019). Geographic and logistical factors drive this range of prices, but it also reflects inconsistent incentives for developing organics management facilities across the state.

5.3. Regulatory Challenges

Regulation of organic waste management facilities is a controversial issue regarding the construction and operation of facilities in the state.

Permitting is not consistent

Duration, expense, complexity, and uncertainty related to permitting is seen by many as a barrier to infrastructure development, especially regarding the process to obtain air quality permits. Facility proponents must obtain permits from multiple local and state agencies that often are not consistent with each other in their requirements and restrictions.

Inconsistent or lack of training among permitting agencies staff was mentioned as a particular challenge by many interviewees. This limitation has resulted in a variance in the knowledge of staff from county to county and, thus, in the application of the regulations. These conditions have been exacerbated by a high staff turnover and high diversity of authority delegation and structures among state, regional, and local permitting agencies. As an example, in many smaller counties, public health staff manage compost facilities within a larger portfolio of many different businesses, including auto repair shops and others. This leads to generalist knowledge for already overburdened staff.

The permitting process with air quality agencies is especially challenging at this time due, in part, to disagreements and unresolved issues related to emissions factors. The air regulations used by the air agencies vary significantly, despite being rooted in a common statute. Local air quality regulations do not necessarily share the same structure or verbiage in some circumstances.

Emissions factors for volatile organic chemicals and other organics management emissions

Air regulations have primarily focused on nonmethane, non-ethane organic compounds (NMNEOC) and ammonia, which cause odors, such as that of a rotten egg smell. Some compounds can react with nitrogen oxide (NOx) to form ozone and other air pollutants. Therefore, there is a current emphasis on prevention of emissions of volatile organic compounds (i.e., organic compounds with low water solubility that tend to be emitted from solid and liquids, abbreviated VOCs).

VOCs are regulated via two approaches: being measured by direct sample collection and analysis or by modeling using *emission factors*. Emission factors are representative values that agencies use to relate activities with their estimated emissions and have long been used as a tool in air quality regulations and enforcement (Thao et al., 2011). Emission factors used in Washington permitting, however, have been criticized because of the reliance on limited and unrepresentative data from source tests conducted in passively aerated facilities in California, mostly between 2000 and 2010. The default emission factors are often an order of magnitude higher than emission factors measured at well aerated facilities, [20] as reflected by the significant variability among facilities used to generate such emission factors (Clements, 2010, ARB, 2015). Furthermore, current emission factors used by state and local agencies do not adjust to local conditions and fail to consider local meteorological conditions and abatement technologies. Local data are needed to establish emission factors that represent current conditions in Washington (see side box for new study).

In addition, some experts believe that methods used to estimate and determine volatile organic chemical emissions from composting facilities are unreliable and inefficient (Carpenter et al., 2020). Existing practices impose a barrier to the construction or expansion of large facilities

Connecting research to regulation

A research project led by the Washington State University (WSU) and Engineered Compost Systems (ECS) to analyze emission factors in industrial compost piles. was recently funded by the Environmental Research and Education Foundation (ERF). Specifically, the research aims to determine and relate emission factors in industrial scale aerated static piles, with operating conditions measured through key performance indicators (KPIs). VOC emissions will be measured by controlling operation settings and characteristics of the feedstock mix, such like the C:N ratio and moisture. The project's goal is to provide regulating entities with guidelines to predict and produce VOCs emission factors based on current and representative da ta for Washington State conditions

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trying to maintain operations at levels below federal Title V triggers. Federal regulation under Title V imposes costly and stringent requirements and controls on operations.

The alternative compliance method for VOCs, direct sample collection and testing, is expensive and not well suited for operations with dispersed emissions such as composting sites (Brown et al., 2020a).

The production of biochar is an emerging technology. There is also growing evidence of significant emissions from these facilities including criteria air pollutants - especially $PM_{2.5}$, NO_2 and ozone - and toxic air pollutants, mostly volatile and semi-volatile organics. Proper design and operation of biochar facilities are

[20] A recent series of air quality management district (AQMD) supervised source tests showed an emission factor (EF) ranging for 0.08 – 0.22 lb. NMOCS/ton, whereas the default EFs in California are 3.6, 4.6, and 5.7, depending on the specific district.

needed to control such emissions and reach comparable or lower emission rates than combustion units, incinerators, and gas combustion (Springsteen et al., 2021).

Measurement of odor emissions

Beyond VOC issues, measurement methods for quantifying *odor* emissions are inconsistent across regulatory agencies in the state. Sources commonly creating odors perceived as offensive by neighboring residents include anaerobic patches, incoming of highly putrescible loads, leachate ponds, overwhelmed/malfunctioning biofilters, grinding operations, screening operations, active composting, and finished compost piles. Whenever odor emissions escape the property boundary of a facility, residents of the area may find the smell offensive and lead to nuisance (San Diego State University, 2007).

There are well-developed and standardized methods for measuring, quantifying, and modeling odors worldwide and in the United States (Coker, 2013). Measurement of odor emissions is performed in odor strength units per cubic meter (o.u./m3) along with the characterization of odors, their persistence, and strength (West et al., 2019). Common standards for these measurements include ISO and ASTM. Local regulators across Washington, however, are reported to lack common approaches to the issue, which has led to the judicialization of complaints' management between the industry and regulators.

5.4. Operational Issues

Operation of organic management facilities involves consideration of environmental, biochemical, and economic performance reflecting feedstock variability challenges associated with food waste, extra needs for anaerobic digestion, and emerging technologies.

Feedstock variability

Facilities often manage an evolving feedstock from municipal collection programs. For example, yard trimmings are a significant portion of the feedstock, and its seasonal variability is challenging to manage and require that facilities develop seasonal-driven.

In addition, secure feedstock procurement is a critical factor that, when unmet, can risk the viability of small-to-medium scale operations. Some interviewees mentioned that the lack of awareness about available waste streams hampers operations, and limited surplus during winter hampers further development of composting operations in less populated areas.

Food waste challenges in composting facilities

The introduction of food scraps as part of mixed stream feedstock presents several challenges to composting facilities. Compared to other organic materials, food waste is highly putrescible (i.e., it tends to rot easily), which requires composters to handle it in a way that mitigates odors and leakages. This mitigation includes additional infrastructure for receiving and stockpiling loads of materials. Food scraps, though, usually represent only 5 to 10% of mixed stream loads in weight, and even less in volume.

Many interviewees stated that the addition of post-consumer food waste to feedstock dramatically increases contamination problems.

These issues are largely caused by the associated increase of single-use plastic foodware products, which may not fully compost or breakdown and may contain toxic substances, film plastic, and more.

Mixed streams including food scraps also degrade differently compared to food-free feedstocks, due to their high moisture and nitrogen content. Although highly nutritive from a product standpoint, food scraps are variable and can impact product homogeneity.

Besides infrastructure and performance, the introduction of food scraps adds to business complexity. Permitting is mandatory for all large facilities that include food scraps, which increases design requirements and operational standards. The latter includes additional documentation, infrastructure, abatement, monitoring, testing, and inspections.

In addition, relations with neighboring communities can be impacted due to the higher odor emissions related to processing these materials, especially if mismanaged. The high moisture and degradability of food scraps increases the likelihood of exacerbating low pH, high temperature, and anoxic conditions in piles. These conditions give rise to significant odor generation and impact overall product quality by locally slowing down materials' degradation. Also, the significantly higher moisture of these residues requires improved management of leachates and increases material handling costs.

Anaerobic digester operational challenges

Failure risks: Failure risks of anaerobic digesters include explosion hazard due to the process's pressurized nature, risk of spills, and accumulation of noxious gases in part of the infrastructure.

Maintenance costs: Maintenance issues associated with anaerobic digesters include significant and relatively frequent equipment replacement due to corrosive gases (Penn State Extension, 2016, Silva and Belli, 2019). Also, expensive maintenance and repairs are needed to avoid leaks and operation stoppages due to the accumulation of inert materials. These inert materials (a.k.a. sands) enter the system along with the desired organic materials.

Lack of renewable natural gas guidance: There is a lack of standards for injecting biomethane into state pipelines, as such definitions depend on pipelines operators. This lack of guidance is a barrier for new RNG projects, as definitions for injection are critical for determining project technical-economic viability. There is a need to update the maximum concentrations levels for gases allowed in injected biomethane. This is because some trace gases that are below the current "non-detect concentrations" can cause significant problems. There are also major concerns about leakiness of existing natural gas pipelines.

Food waste variability: The high variability in food scrap loads can impact the biology of digesters and cause the process to deviate from optimal temperature and moisture conditions. Relative to more homogeneous feedstocks, mixed materials require more pre-processing, which adds to already high operational costs. The higher variability can also lead to less consistent products that impact perception of quality and reliance.

Also, compostable food packaging has not generally been digestible but new innovations in digestible packaging is coming online in Washington and in the EU.

Nutrient management: Digestate, the liquid by-product obtained from the digestion process, is significant in volume and exhibits a high biological oxygen demand (BOD), which requires proper management. In addition, the solid residuals from digesters need to be land applied in large areas or undergo further post-treatment, for example, through composting.

Vermiculture

Vermicomposting has been shown to be an efficient method for managing organic matter in small quantities. For large feedstock facilities, it is less feasible because of the need for considerable area of lands. This is because the depth of the material must be less than two feet, as the mechanical load and temperature must be within stringent parameters so that the worms can survive (Muralikrishna and Manickam, 2019). Vermicomposting also requires significantly more labor compared to traditional composting. Useful inclusion of worms in small to moderate-scale operations has been shown to be successful, although, to date, this is limited to managing liquid food-waste slurries and process effluents such as dairy wastes.

5.5. Contamination

Contamination from other materials, such as plastics, glass, herbicides, and pesticides, is a persistent issue that impacts the solid waste management industry. Contamination is one of the most salient barriers identified for incorporating compost into farm fields (Corbin et al., 2014).

Plastic and glass

The four most persistent contaminants at compost facilities are plastic films, plastic garbage bags, rigid plastics, and glass (OCRW, 2017). Feedstock loads containing single-use plastic food serviceware and plastic bags are challenging to manage. Many facilities do not accept post-consumer food waste because of the inevitability of these plastic products tagging along.

Produce stickers are also often mentioned as a persistent and unwelcome feature that lowers the quality of compost, as these do not break down (OCRW, 2017).

Glass is especially a challenge as fragments usually persist in finished products given the difficulty of their removal (Hills et al., 2015, OCRW, 2017). Glass poses a significant safety issue for all end-users, and especially those raising root crops which can incorporate shards and hard plastic in vegetables (Collins et al., 2015, OCRW, 2017).

Plastic film piece at compost facility.

Clopyralid carryover in compost impacting plant. *Photo: OR State Extension*

When present in finished products, plastic or glass fragments significantly lower customers' valorization of compost and raise questions about the safety of its application. Specifically, farmers have reported that low-quality compost applied on you-pick fields can lead to unsightly conditions for customers (Collins et al., 2015). Such challenges have a significant impact in agriculture's price-sensitive market (Hills et al., 2019). Farm operators have, for example, perceived a risk that pieces of rigid plastic or glass can end up in silage fodder destined to dairy cows. Dairymen even opted out of a pilot project in Snohomish County where they were offered free commercial compost because of such possibility.

Clopyralid

The herbicide Clopyralid is a contaminant of compost made from agricultural waste, as it is often used on grass hay and some grain crops (WSU, 2005). Contaminated products have caused toxic effects in certain crops and landscape operations, especially in eastern Washington. For example, in 2000, the City of Spokane was forced to shut down its compost operations due to such contamination. The limited yet persistent presence of this contaminant has been an additional reason for the limited and slow adoption of off-site compost in agricultural operations. Currently, the use of this herbicide is only allowed for registered industrial users.

This chemical, however, continues to pose a hazard for compost facilities processing grain crops and grass hay. These facilities need to regularly conduct expensive tests in their finished compost, which adds up within already tight revenue models for these operations. Persistent herbicides and pesticides are also a hazard for the environment and for hay-based pelleted food used in zoos.

Oregon recently announced that they plan to phase out all uses of Chlorpyrifos by the end of 2023, except for commercial pre-plant seed treatments, granular formulations, and cattle ear tags (Samayoa, 2020).

Compostable plastic-like and fiber-based food service products

A particular type of contamination comes from compostable plastic-like food service products. The degradability of these products in individual compost facilities is significantly variable even when certified by a third-party certifier such as the Biodegradable Products Institute (BPI) Although recently, the Washington State-based Compost Manufacturing Alliance has developed a product testing program that is directly keyed to breakdown at compost facilities.

Handling these bio-plastic products creates several complications for facilities such as operational costs, product quality issues, and marketability limitations. This is because the products need higher temperatures and longer processing times to degrade. Furthermore, many interviewees alluded to a "Trojan horse" effect when accepting these materials, as they contribute to higher rates of contamination associated with plastic look-alike products.

Plastic bags are a major problem and are strongly discouraged or disallowed. *Compostable* bags are mostly disallowed, with some exceptions at some facilities, because they do not break down fast enough at their processing times, forcing composters either to recirculate them or screen them out. Also, compostable bags are difficult for operators to distinguish at a glance from plastic bags. Both plastic and compostable bags pose additional complications by wrapping in processing equipment.

Fiber-based compostable foodware, such as paper and wood products, are more accepted in operations than their compostable plastic-like alternatives, although they also pose challenges for facilities accepting them. The first issue corresponds with confusion and "wishcycling" behaviors among customers who do not see differences between plastic-like and fiber-based compostable products. There are also issues with poly-coated paper which many consumers assume to be compostable as a type of "food soiled-paper." Thus, these coffee cups, frozen food boxes, and paper plates end up in the incoming feedstock.

Recent research demonstrates that per- and polyfluoroalkyl substances (PFAS) contamination in compost is likely, although at lower levels than the PFAS found in wastewater plants' biosolids (Choi et al., 2019). This problem will diminish, however, due to Washington's recently enacted law (HB 2658, recodified as 70A.222.070 RCW) that phases out foodware products with PFAS when technically acceptable alternatives come on the market. The law requires Ecology to determine whether there are safer alternatives available for specific food packaging applications. In February 2021, the agency published a report identifying safer alternatives for four specific applications – food boats, pizza boxes, plates and wraps, and liners. The ban on these products would become effective in 2023 (SGS, 2021).

5.6. Demand and End-Markets for compost products

Revenue models for organic waste management operation depends on tipping fees and sales. Currently, demand for compost products lags far behind its potential, especially from agricultural operations. Only 5% of Washington's compost production is used in agriculture (Commerce, 2020).

Tipping fee challenges

Tipping fees (i.e., charges at facilities for delivery or drop-off of feedstock materials) represent roughly 20% to 50% of the revenue, depending on how much emphasis is given to product quality. Tipping fees are not regulated, and thus, are negotiated between organic waste management facilities and haulers. Negotiated fees are defined by market forces, processing costs (which can be driven by contamination levels), competition, and substitutes (i.e., landfilling fees).

The relatively low number of facilities leads to a lack of competition and, thus, drives prices up. Another issue is that permits granting service areas to haulers can impact tipping fees, which can inhibit the development of small and medium scale composting facilities. Nevertheless, expanding organic waste management markets are still present in certain areas of Washington that observe increasing fees driven by demand.

Demand challenges

End-users often have difficulty understanding the benefits of different soil amendment options, which is partly explained by limited information on product specific characteristics and potential benefits. Adoption is also hampered by the lack of information on and homogeneity of product composition, especially regarding its C:N ratio, NPK content, and nutrient availability.

The bidding purchases of big players like government are critical for setting quality standards for the entire industry. This has been the case with the Washington State Department of Transportation (WSDOT), even though they emphasize that their specifications are only for their specific uses.

There is large potential demand in the forestry and agriculture sectors, especially in the eastern part of the state. These sectors, however, are highly risk-adverse in terms of contamination avoidance and returns-related uncertainty. Transportation of finished materials from western counties (where the largest sources are; see Figure 14, in Chapter 3) is expensive, faces farmer skepticism, and may not be economically favorable in all cases (Hills et al., 2019). Currently, compost can cost up to 2-3 times more in eastern than western Washington, and more work is needed to make compost feasible and available to serve this market (Commerce, 2020).

Cost of spreading equipment: Lack of spreading equipment impedes the adoption of compost products in agricultural operations (Hills et al., 2019). Both compost and digestate require the acquisition of spreading equipment to be incorporated in operations (Brady, 2019), which is relatively expensive considering the tight margins under which farms operate. The required investment makes the inclusion of compost in operations unlikely to occur, because farmers perceive uncertain benefits of the material. Thus, investment and product adoption are often considered unjustifiable (Chen et al., 2019).

Some conservation districts – for example, those in Snohomish, King, and Spokane counties - have purchased manure/compost spreaders to loan out, although issues arise when multiple small farmers need the equipment at the same time. Barr-Tech, in Lincoln County, has a rental program (see sidebox).

Lack of awareness: Farmers' reluctance to adopt these types of amendments compared to alternative highly standardized petroleum-based products on the market is partly due to the limited information available about the effectiveness of compost and digestate in improving crop yields. Thus, farmers see no clear benefit of using compost or digestate compared to other amendments and fertilizers they are used to and know well (Commerce, 2020). Perceptions and prior experience with quality issues in compost products can impede adoption by farmers.

Supply disconnect with demand: High variability among options and ample availability of low-quality compost products contributes to a lack of confidence in these markets. The operation of large-scale compost facilities processing municipal streams is encouraged by organic waste reduction goals but is not well-connected to demand for compost products Specific end-markets' perception of the entire industry and product quality have been adversely impacted.

Contamination issues: Observable contamination – especially derived from plastics – is a relevant driver of compost's lack of demand, given its uncertain persistence and impact on crops (Commerce, 2020). A pilot project that offered free compost to western Washington farmers (Snohomish County) recently demonstrated the degree of impact of currently accepted levels of contamination for plastic (5%, in weight) and film plastic (1%, in weight). Specifically, the pilot failed due to lack of interest among participants who complained that persistent contamination made the incorporation of compost unattractive to them,

Compost spreading equipment rental

One barrier to agricultural use of compost is the lack of spreading equipment. Farmers hesitate from investing in such machinery to avoid sunk costs if they perceive compost as a potentially risky option for their operations.

One of Washington's biggest compost producers – Barr-Tech – is addressing this barrier through their Pike Rite spreaders rental and sale service. They provide a range of sizes and types of spreader giving customers access to test compost application with rented equipment, which is accompanied with the possibility of later acquisition.

even if acquired for free (Collins et al., 2015). Contamination also precludes access to the organic market as, currently, both disposable and compostable plastic products are not allowed into certified organic farms operations (USDA, 2015).

Lack of widespread public procurement standards: Additional potential demand appears to be stagnating because of poorly defined or inconsistent purchasing guidelines and requirements by public agencies. The Washington State Departments of Transportation's (WSDOT) public procurement standards are focused on their specific uses along highways, especially for controlling erosion and promoting vegetative coverage and species diversity. WSDOT reviewed these standards and shifted from coarse to medium screened compost to reduce contamination levels. The agency regularly communicates that its standards should always be evaluated for specific use conditions when used as guidance by other parties. Specifically, the agency's specifications sheet requires compost to be tested in accordance with the USCC Testing Methods for the Examination of Compost and Composting (TMECC) 02.02-B "Sample Sieving for Aggregate Size Classification." WSDOT standards must meet specific physical criteria (Table 6) (WSDOT, 2020a):

Ecology's standards for compost products are defined in WAC 173-350-220 which sets limits on the quantity of metals, physical contaminants, sharps, and additional testing parameters such as pH, biological stability, and fecal coliforms/salmonella.

The differences between these two agencies includes not only disparate requirements but also different testing methods for verification. Furthermore, Ecology's Stormwater Management Manual for Western Washington defines additional standards for using compost for water quality purposes. Local governments in western Washington have been required to base their regulations on the manual, with more stringent specifications for carbon to nitrogen ratio and biosolids, manure, and organic matter content than those required per WAC 173-350-220 (ILSR, 2016a).

5.7. Knowledge

Knowledge gaps and limited staff capacity impact the performance of the organics

Table 6 WSDOT Compost Standards

Variable	Range
pH	6.0 – 8.5
Physical contaminants	< 0.5% by weight
Organic matter	≥ 40% by dry weight
Soluble salt content	< 4.0 mmhos/cm
Maturity	> 80%
Stability	≤ 7 mg-C/g OM/day

Compost accepted feedstock: wood waste, yard debris, post-consumer food waste, and pre-consumer animal-based wastes, pre-consumer vegetative waste.

management industry since multiple actors design, operate, manage, and regulate it.

Technical guidance for facilities

There is room for the industry to fully incorporate best management practices into facility design and operation. Regulations often focus on abatement measures. Regulators and designers need to understand how facility design and operations determine process conditions, and how process conditions determine air emissions (VOCs and odors). Guidance in the design and management practices could allow for further expansion of operations and improvement of environmental performance (O'Neill, 2021). Limited knowledge may also be preventing some governmental planners from developing organics management solutions that meet their needs and budget.

There is a desire for clear operational standards for composting and anaerobic digestion facilities, mainly because such parameters are effective and simple indicators of facilities' performance, including odors and volatile organic chemical emissions. Ecology's Good Management Practices guide is a valuable resource that provides regulatory orientation and information about optimal operational standards (Ecology, 2013a). The document's last update, however, was in 2013 and its guidance has not been leveraged for simplifying monitoring and reporting. According to several of the experts interviewed in this study, monitoring and enforcement could benefit from focusing on KPIs under ranges that reflect BMPs.

Gap between research and innovation

There is limited connection between research institutions and innovation on new models and technologies for the organics management industry. Lack of funding likely adds to the disconnect, which in turn may be causing the underfunding of some of the most salient business models that the industry has created in recent years, especially for highly localized digesters and in-vessel composting equipment.

Data reporting is limited

State regulations currently require facilities to provide annual reports to Ecology, but the required data are limited. These limitations hamper further development of the system from both public and private actors and creates significant gaps in information about permit-exempt facilities. Furthermore, limited data about organic product procurement and characteristics are available. Solid waste managers in local governments could benefit from access to broader and more detailed information about how these products are distributed and their specifications.

5.8. Coordination and Competition

A lack of strong coordination among public actors and limited competition among existing facilities inhibits the growth of the organics management industry and reduces its effectiveness.

Lack of consistency and coordination across the state

Many interviewees commented on inconsistent practices from public agencies and mismatched collection programs between neighboring jurisdictions. Interviewees highlighted how the lack of communication and standard guidelines between authorities impacted critical processes such as permitting and public procurement. The discoordination further increases uncertainty for facility operators, constrains their financial standing, and limits potential development plans. Inconsistencies such as disparate testing methods and product requirements can increase the system's overall costs and contribute to inconsistent product quality.

Limited competition

There is strong desire in *urban* areas for organics diversion by residents and decision-makers. Limited competition (i.e., few compost facility options), however, impacts local governments' capacity to plan and divert their organic materials. It also limits local jurisdictions' capacity to negotiate tipping fees or develop competitive procurement plans. Local governments also do not have budgets for prospecting appropriate organic materials for their needs. This contributes to fewer options available for composting in some of the state's low-density areas. Also, there is not necessarily an easy path for local governments to make the change.

Disconnect of organics management initiatives from climate change and other policy directives

Interviewees noted a general lack of political will for further expanding the organic management system in the state. Failing to account for the social costs of disposal and its environmental justice and climate change implications further hampers diversion of organics from landfills. In sum, the public has limited awareness of the relationship between organics' disposal and their associated greenhouse gas emissions in landfills.

Chapter 6: Opportunities for Improving and Expanding Management of Organic Materials

Constant innovation in organic waste management allows operators to perform better economically and environmentally, while government support provides capital, incentives, and product demand to foster operations. There is also vast potential demand for organic management products, especially from agriculture. The need to address climate change and address environmental justice are additional drivers for improving organic management operations. This chapter summarizes major themes of opportunity in Washington for improving and expanding the management of organic materials. Specific recommendations are detailed in Chapter 7.

6.1. Innovation and Technology

The organic management industry is continuously evolving as researchers, engineers, and entrepreneurs generate new processes and technologies. Many of the state's facility operators, consultants and researchers are piloting new management methods, scales of production, and processes that connect the infrastructure with new material streams. At the same time, engineering firms continue to develop equipment to help address contamination and better incorporate food scraps into operations initially designed to take green waste (yard debris and agricultural organics), dairy waste, and other non-food wastes. Development of the industry, especially in less dense and small-scale locations, can be a strong driver for job creation and expanded access to more sustainable organic waste management.

Small scale

New formats and scales of digesters and composting facilities continue to expand the organics management field (KC SW Division, 2019). These new business models and approaches complement the existing standard that is based on centralized operations. On-site and small-scale operations currently in development can help mitigate social and environmental (notably transportation-related) costs associated with larger-scale organic management operations. These operations can drive investment and local job creation, although careful design of their business models is necessary to ensure their long-term viability. Further assessment is still necessary to demonstrate how well this localized approach compensates for the higher economies of scale of big-scale operations.

Small-scale programs often rely on local governments' capacity to fund them (which have had tight budgets in recent years). Further coordination and additional funding available at the state level could improve the long-term sustainability of these kinds of programs.

Alternative organic materials management methods

Alternative approaches using insects or worms are also proving potential for development in less populated areas. For example, two worm-based biofilter facilities operate in eastern and central Washington, where they have innovated treatment of wastewater and dairy slurry through biological filters based on digestion by worms. The *Biofiltro* system reduces dairy wastewater water quality loads realizing 52% reduction in BOD, 85% in total suspended solids (TSS), 80% in total Kieldahl nitrogen (TKN), and 83% in total phosphorus (TP). A key benefit is that these systems can operate at ambient conditions.

Promising technologies based on black soldier flies and mealworms' cultures offer further development and innovation opportunities in Washington as they are scalable methods and allow for processing food waste.

Five units at the Monroe Correctional Complex run facilities using vermicompost, bokashi, and black soldier fly methods as part of their waste management and inmate employment programs, which represent the best-known applications of these methods in the state. The system started in 2009 and aims to process most of the facilities' food waste, currently processing nearly 120,000 pounds of food waste a month.

Worms are also being used to treat over 500,000 gallons per day of wastewater from dairy and winery operations in two facilities located in eastern Washington. The system processed a total of 30,000 lbs., of food waste a month during 2019 and aims to manage a larger share of the 120,000 lbs. of waste per month.

Co-digestion

Co-digestion is as an area of significant potential which takes advantage of existing anerobic digestion capacity for treating solids derived from wastewater treatment facilities and other operations, by bringing in nutritious streams like food waste. Several initiatives are piloting the diversion of food processing waste at transfer stations. Commercial food waste is mechanically separated from its packaging and also large chunks like bones, and then processed into slurries for their integration into large scale existing digesters. This approach's potential is significant in California (CA Water Boards, 2019), and Washington's largest wastewater treatment facilities could integrate it.

New technologies

Continuous development of new equipment and processes can help address contamination and diversification of organic materials accepted as feedstock. One example is de-packaging equipment which is used for commercial food waste. This type of equipment entails, however, a dilemma. Although de-packagers can help increase the amount of food waste captured, they can also increase the level of plastic contamination in composting operations. This is because the equipment can generate small shreds of plastic film which mostly gets pulled out during the process but does not get completely captured. These shreds can end up in final product or even escape into the environment as litter or water-born debris.

Other technologies include those to screen and recirculate material to sort out some of the contamination at the end of composting processes. "Up the pipe" measures can further reduce contamination in organic waste management operations, typically at a lower cost than those implemented by facilities. Surveillance technology can be used by hauling companies to reject contaminated loads before they reach management facilities. Finally, steam treatment is a promising technique for addressing transportation limitations related to the apple maggot quarantine, although the verification of its efficacy and economic viability is ongoing. More innovations are described in the Side Box.

> ### *Washington's innovation ecosystem*
>
> Innovative technologies being developed in Washington include:
>
> - Treatment technologies for liquid organic waste streams based on mechanical vapor recompression, which allows to obtain clean water, aqueous ammonia, and dry solids suitable as soil amendments (Sedron Technologies, n.d.).
> - High performance low-cost packaging and utilization of food waste as feedstock for PLA products manufacturing.
> - Second generation biofuel feedstocks and fermentation.

Co-benefits

There is a growing body of knowledge about the benefits, beyond nutrients and moisture retention, of applying compost or digestate in farming operations and ecological restoration initiatives. As an example, dried digestate used in bedding appears to be beneficial for animals due to the presence of microbes. WSU researchers and others continue to expand their understanding of the benefits and carbon sequestration potential of applying compost and digestate to farmland and the agricultural industry.

The possibility of using renewable natural gas generated from digesters to charge fuel cells appears to be a means to incentivize industry growth even in consideration of electrification and other competitive renewables.

Performance-based monitoring

A complete understanding of the relationship between operating conditions and emissions can significantly mitigate the impact of large-scale facilities and improve their relationships with neighboring communities and regulators. Several interviewees ascertained that regulation of facilities could incorporate best management practices to simplify monitoring relative to the current approach based on end-of-pipe measurements and abatement. Such an approach has also been analyzed as cost-effective outside of Washington State (CalRecycle, 2020), and it represents a cost-effective means for regulating climate change emissions.

6.2. Grants and Government Support

Composting and anaerobic digestion operations would benefit from receiving subsidies and grants from governments where organics management integrates broader climate change mitigation strategies and comprehensive waste reduction plans. Increased financial support and technical assistance for public education and outreach would help provide the industry with increasingly reliable and better feedstock.

Anaerobic digester support

There is significant existing support for anaerobic digestion. Federal support for anaerobic digestion continues to provide startup funding, while the state continues to invest in this technology through the Department of Commerce. This support from state and federal agencies provides the industry with incentives to build and expand existing operations.

At a federal level, EPA's program AgSTAR provides funding for construction of digesters associated with agricultural operations. The program continues to fund new projects, and it has evolved to incentivize the inclusion of additional waste streams such as food processing waste (EPA, 2020m). The federal Department of Energy also supports research and development of bioenergy technologies based on organic waste, including urban and suburban waste, and how to improve the performance of existing facilities (DOE, 2019).

At the state level, the Department of Commerce recently awarded Clean Energy Fund grants for four projects targeting anaerobic digestion facilities (Commerce, 2020). Several tax exemptions for digesters operating in the state also seek to incentivize the industry's lagging development in the state (DOR, 2020). Originally established in 2001, these incentives were provided for digesters operating as part of dairies. The program was expanded in 2018, with the passage of SB 2580 to include digesters processing any type of feedstock (DOR, 2018).

Federal incentive through the Renewable Fuel Standard program (RFS) is a significant stimulus for the industry. Facilities would benefit if the program were to set ambitious and timely renewable volume obligations (RVOs) for petroleum refiners and importers. The renewal of the RFS program and the establishment of eRINs to support electromobility could also bring more certainty and market opportunities for the industry.

Additional potential opportunities include:

- Establishment of new state LCFS programs for both pipeline RNG and e-LCFS, such as Washington's HB 1091.
- Creation or expansion of grants and loans offered by the United States International Trade Commission (USITC).
- Expansion of available funding for the rural energy for America program (REAP) and creation of a specific breakout for anaerobic digestion projects.

Compost support

States and local governments continue to foster the development of their organic management systems nationwide, but less so in Washington in recent years. Interviewees highlighted the experiences of Portland, OR, New York City, Vermont, California, and New Jersey in supporting the expansion and upgrade of their organic management systems. Significant grants for infrastructure and equipment and organic waste bans appear to be effective means for propelling organics diversion.

The maturation and expansion of public education and outreach programs focused on organic materials management have increased public awareness about the industry, promoted customers' cooperative behavior, and reduced the level of contamination in organic materials streams.

National trend: Increasing management of organic material

Nationally, the number of municipalities that divert yard debris for processing has been increasing. The increase of drop-off organic collection programs, for example, has gained momentum nationwide and is an attractive option for less-densely populated areas with limited budgets (Streeter and Platt, 2017).

Initiatives seeking to increase energy efficiency and clean and renewable sources drive the anaerobic digestion industry's development. One example is the City of Seattle's Metered Energy Efficiency Transaction System (MEETS) initiative, which could offer small-scale digesters paths for accounting as energy efficiency projects.

Utilities in the state represent a potential demand source because of their goals to reduce carbon-intensity of their operations using options such as renewable natural gas (BioCycle, 2020b). These initiatives and others represent a path for organic waste management development in the context of competitive solar and wind energies.

Disaster response

Large amounts of organic debris can result from major disaster events such as ice storms, windstorms, and wildfires. Processing operations that are available year-round or that ramp up for seasonal volumes (e.g., yard debris) might have capacity to help with processing and marketing some of this disaster debris material. These facilities, however, can lack needed space required to accept and store the additional material. End products, such as ground mulch or biofuel, might also disrupt and compete with markets for ongoing feedstocks. Although this interplay is most apparent in regions where hurricanes occur, Washington could learn from such areas and emergency managers on how to integrate ongoing facility and operators needs with these surge demand events.

6.3. Potential Demand

The potential demand for products derived from organic management methods surpasses the supply that could be reached by processing all inedible organic residues disposed of in landfills or incinerated.

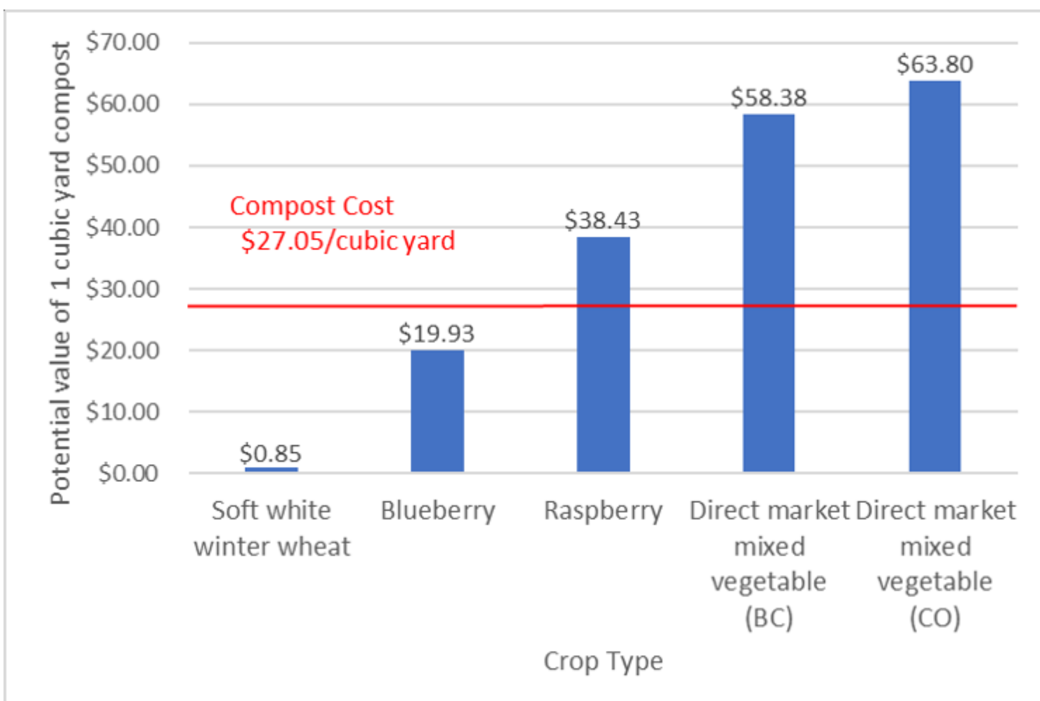
Growing markets: high-value crops and organic farms

Some expanding agricultural markets, such as niche high-value crops like cannabis, raspberries and blueberries represent a potential increasing demand for digestates and compost. Organic farms have the potential to benefit from incorporating compost under existing USDA and WSDA organic certification requirements (USDA, 2015, Hills et al., 2019). In 2019, statewide organic farm area peaked at 148,280 acres after four years of growth driven by the increase of tree fruit, grain, pulse, and oilseed organic land in the state (Granatstein and Kirby, 2020).

For high value crops, it has been calculated that the value of compost can exceed the cost of its acquisition (Figure 24), specifically for crops such as raspberries and direct market mixed vegetables in British Columbia and Colorado. Although estimates, these figures show that compost can have a wide range of values depending on the type of crop and soil conditions, and that these can exceed the associated cost.

The growing marijuana industry expands the demand for compost by using it to differentiate

Figure 24 Comparison of cost and potential value of compost for a number of crop type scenarios



Graph from Hills (2020). Comparison of cost and potential value of compost for a number of crop type scenarios. Enterprise budgets for direct market mixed vegetable scenarios were from British Columbia (BC) and Colorado (CO). Figure from data in Hills et al. 2019 products through flavors and aroma. Several interviewees also referred to cherry orchards and wineries as attractive markets for compost producers, especially west of the Cascades. The most salient potential is the expanding organic agriculture market for apple production. Current US organic certification requirements allow compost and digestate operations that meet USDA standards to register their products as suitable for certified organic production with the state through WSDA.

Procurement

The public sector represents a critical end-market for organic management products to be used for infrastructure projects, public lands administration, and restoration projects. Indeed, compost is one of the best management practices for erosion control (WSDOT, 2020b). As Washington's HB 2713, *An Act Encouraging compost procurement and use* (2020),[21] goes into effect and begins to encourage agencies and local governments to acquire compost, coordination among these institutions will be key for expanding these markets and its development. Initiatives like King County's standard public procurement contract (See sidebox) fosters clarity among institutions regarding compost uses and associated standards and testing, thus sustaining and developing the industry.

King County's standard public procurement contract

King County's standard public procurement contract seeks to increase compost use in county projects by offering agencies a single contract for purchasing compost. The contract's structure includes an invitation to bid (ITB), a geographical division (i.e., region) of the county, and a reporting requirement. Specifications also closely follow procurement standards used by the City of Seattle and Washington's departments of Ecology and Transportation.

Compost public procurement is part of the King County's Sustainable Purchasing Program (SPP), which was implemented in 1989, and requires government agencies to purchase environmentally preferrable products, including compost (ILSR, 2016).

Incentives

The state's *Clean Energy Transformation Act* offers an opportunity to expand renewable natural gas generated by sources like anaerobic digestion.[22] The law requires utilities to reach carbon neutrality by 2030 and a full renewable portfolio by 2045. As a renewable fuel, renewable natural gas can replace natural gas and take advantage of its existing infrastructure. The *Washington Energy Independence Act*s related Renewable Portfolio Standard is a current driver motivating utilities to include renewable natural gas. It is projected to continue to incentivize the fuel's adoption (WSU, 2018b). This policy is especially relevant as utilities' mandate to provide service with least-cost gas supplies is a considerable barrier to the adoption of RNG (Biocycle, 2020b)

[21] HB 2713 passed the legislature, but Governor Inslee vetoed the portion of the bill that would have provided cash incentives to farmers for compost use. He vetoed this portion due to concerns about protecting the state budget due to COVID-19 economic impacts. The intact portion of the law encourages local municipalities to purchase compost made from feedstock from their area.

[22] See the Revised Code of Washington's Chapter 19.405 "Washington Clean Energy Transformation Act" available at: https://app.leg.wa.gov/RCW/default.aspx?cite=19.405

Industry-driven efforts

As zero waste and carbon neutral (a.k.a. net zero carbon) goals become more common, food production and grocery industries are embracing more ambitious strategies to increase their sustainability performance. While prioritizing food waste prevention efforts, these industries are also embracing composting and anaerobic digestion to cut costs down while allowing them to meet their sustainability goals. As an example, Starbucks, Unilever, and Dairy Farmers of America recently joined Vanguard Renewables to launch the Farm Powered Strategic Alliance. The initiative seeks to reduce food waste in the industry's supply chain through waste reduction and repurposing leftovers through Vanguards' farm-based digesters (Redling, 2020).

Consumer education and awareness

Several interviewees noted that demand is hampered by existing knowledge gaps regarding compost, digestate, and other products benefits and uses. Continued education and awareness efforts would help cement the adoption of these alternatives, especially if accompanied by access to financial support and equipment. Also, climate change concerns by the public are prodding the food production industry to adopt more sustainable practices as their customers demand it and penalize laggard performance. A recent documentary *Kiss the Ground* and other films and grassroots initiatives are helping to raise the awareness of regenerative agriculture and the role of environmentally friendly soil amendments for its development.

6.4. Legislative action in other states

Initiatives approved in other states provide innovative policy ideas and preliminary evidence of their effectiveness.

Disposal bans

Several states and cities have banned organics from landfill disposal and incineration. Drivers for these policies include climate change (i.e., methane reduction) and food diversion to feed people. These policies prove effective in fostering waste reduction and organics management like compost and anaerobic digestion. As part of some bans, several states and cities have required organic waste emitters to subscribe to organic materials collection if available options are near their location. California, for example, in 2016, enacted SB 1383 which requires a 75% reduction in organic waste disposal by 2025, compared to 2014 levels. The law also requires that not less than 20 percent of edible food that is currently disposed be recovered for human consumption by 2025. The opportunity of aligning the West Coast on best practices could leverage existing efforts further.

Extended producer responsibility

Implementing an extended producer responsibility program for packaging and printed paper is also an opportunity for reducing contamination in organic waste streams and tackling cross-contamination between the recycling and organics collection systems. Extended producer responsibility approaches in other countries have been shown to be a practical approach for industries to fund and operate programs to manage the waste generated by their products. Interviewees identified plastic packaging and products (which includes foodware) as primary sources of contamination in organics diverted streams. Best practices for designing and implementing these policies in nearby Canada's British Columbia province, the European Union, and elsewhere provide ground to Washington to pursue such an approach.

Carbon pricing

The urgent need to reduce greenhouse gas emissions through carbon pricing approaches has also prompted growing momentum for policy action. Carbon pricing has proved to be an effective means for reducing greenhouse gas emissions by charging emitters for carbon-intensive activities, such as energy and transportation. Carbon pricing could significantly impact the organics management system by charging methane emissions derived from organics disposal and accounting for the benefits of carbon sequestration related to composting and other options. Pricing carbon could help foster the development of anaerobic digestion by incorporating carbon's cost into non-renewable gas supply sources (BioCycle, 2020b).

Chapter 7: Recommendations

Washington should expand and improve its organic materials management system to respond to the increasing issue of the amount of garbage generation and disposal. By better responding to the challenge of preventing organic materials from being landfilled or incinerated, the state could significantly reduce greenhouse gas emissions and continue to lead other states in the fight against climate change. To do this, we recommend that state leaders consider actions that have been categorized into eight themes:

1. Make systemic changes in organic materials management capacity and waste diversion.
2. Improve collaboration between the industry, the government, and related actors.
3. Expand capacity and markets for organic material management and products.
4. Improve performance of the organic materials industry and their regulating entities.
5. Revise permitting to facilitate waste reduction with environmental quality.
6. Support innovation in organic materials management to diversify and expand the industry.
7. Improve standards for an efficient and clean organic materials management industry.
8. Improve contractual processes between the government and organic materials processors.

These recommendations bring together research and conversations with 61 materials management experts in Washington. Recommendations are meant to be actions that legislators, agencies, and others can incorporate into their strategies and goals.

7.1. Make systemic changes

Carefully crafted policies are needed to further incentivize diversion of organic materials from landfills and incineration. Policies can orient industry actors' plans and strategies by setting requirements and reduction targets, reducing uncertainty, aligning public and private efforts, incorporating carbon pricing, and addressing supply and demand issues.

A set of six specific actions is described below:

Reduce disposal of organic materials in landfills by 90% relative to today's levels. Ensure high-quality feedstock for the organic materials management industry and incorporate appropriate backstops (to avoid "diversion for the sake of diversion") as part of the policy development

Bans are an effective approach for diverting organic waste by mandating direct reductions in the solid waste management system (Sandson et al., 2019). Several states – California,[23] New Jersey,[24] and Vermont,[25] among them - have enacted bans on organic waste disposal and have seen a concurrent expansion of organic material management facilities and increase of food donations. Such policies also foster food waste reduction at grocery chains and restaurants operating in these states, which can trigger new programs that the industry can replicate elsewhere. These measures signal diversion goals and inform investors and private actors about available feedstocks and funding.

The legislature should carefully consider what materials to include and the timeline for the reduction targets. A phased process allows actors to prepare and respond to increasing reductions while also allowing processing capacity to expand accordingly and ensure that contamination rates decrease, rather than increase. Existing examples show that these policies benefit from establishing thresholds for generators based on the amount of waste they produce and their distance to waste processing facilities. These limits are dynamic and provide smaller generators and small-scale businesses with additional time for adapting to the new regulations. This policy could act as an umbrella for several other policies providing funding, requiring coordination, and reforming regulatory processes.

Careful design is necessary to ensure that waste reduction goals follow the waste management hierarchy, i.e., encouraging waste prevention and food recovery as a primary strategy. Importantly, the policy should set standards and backstops that ensure the provision of high-quality feedstock to the organic materials management industry. Failure to ensure low contamination levels would lead to marginal

[23] California's SB 1383 *Short-Lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills* mandated a 50% reduction in organic waste disposal from 2014 levels by 2020, and a 75% reduction by 2025. In addition, the bill required that no less than 20% of edible food currently disposed be recovered for human consumption by 2025 (CalRecycle, 2020).

[24] New Jersey's S3027 *An Act concerning the reduction of food waste and supplementing Title 13 of the Revised Statutes* establishes a goal of reducing the amount of food waste generated annually in the state by 50 percent of the amount generated in 2017, by the year 2030.

[25] Vermont's H.485 *No. 148. An act relating to establishing universal recycling of solid waste* banned disposal in trash and landfills for any person generating any amount of food residuals beginning on July 1, 2020.

materials reaching the waste management system, negatively impacting the marketability of the finished products, endangering general public credibility of the system, and harming relationships between public programs and their industry counterparts.

Existing food waste reduction goals set in Washington in 2019, by HB 1114 "*An Act Relating to reducing the wasting of food in order to fight hunger and reduce environmental impacts*" can also act as a reference for an organic material ban by providing a reduction target for 2030 that can be complemented and projected through the new legislation. Setting such targets would address organic waste and food waste's significant roles in greenhouse gas emissions and bring much-needed certainty among the solid waste management system players, encouraging investment in and development of future capacities. It is crucial, though, that any policy banning materials from their current disposal default option be accompanied by a detailed plan involving stakeholder input.

Increase landfill tipping fees to reflect full environmental costs compared to organic materials management methods and support higher-hierarchy organic waste management approaches

The level of tipping fees at landfills and transfers stations are strong drivers for the degree of waste diversion observed in communities. The large range of fees observed in Washington is partially explained by geography and specific logistics challenges (such as off-island transport). Nevertheless, there is considerable inconsistency of fees across similar jurisdictions (see Appendix 10 for specific values).

Jurisdictions within regions should conciliate the range of fees and incorporate organics disposal's social costs. Social costs include higher greenhouse gas emissions and disparate health effects and nuisance to communities impacted by landfill operations (Brady, 2019). A more consistent set of fees would incentivize further expansion of organics management programs while increasing the local and overall competitiveness of organic materials management facilities statewide. Furthermore, additional revenue from these fees could be directed towards supporting programs and incentives for higher hierarchy organic waste management options. This could include expansion of education programs for reducing household food waste, fostering food recovery programs, and supporting organic waste materials industry initiatives.

This policy approach could be complemented by measures such as flow-control laws or policies to set a statewide minimum cost-per-ton for landfill disposal. This is important in order to avoid material being redirected to cheaper facilities.

Foster energy markets for biogas by facilitating electricity generation for e-vehicles through LCFS programs and setting minimum content of renewable natural gas (RNG) in gas utility contracts associated with industrial uses that are not easily converted to electricity.

The Washington's Clean Energy Transition Act (CETA) aims to phase out electric utilities' natural gas demand by 2045. Thus, this energy source will decline as the state continues to develop renewable sources and as distributed energy in cities' electricity grids expands. Therefore, renewable natural gas (RNG) generation will become attractive for gas utilities transitioning towards cleaner energy sources while leveraging the existing infrastructure (Coppedge et al., 2012). RNG generated from dairies is estimated to be carbon negative, and its generation from food waste could also help utilities significantly reduce their greenhouse gas emissions. This approach is particularly effective for uses where an electrified solution is not able to be made available, such as some industrial uses. The Washington Utilities and Transportation Commission (UTC) could guide utilities' transition to a cleaner energy matrix by requiring a phased increase of renewable sources, including RNG.

Biogas production could also be linked to electricity generation for e-vehicle use through LCFS programs run in Oregon and California. This approach is relatively new and provides a revenue path for small and medium biogas generators. Facilities convert biogas to electricity that is then sold out-of-state to be used as a fuel substitute. This business model could be fostered by facilitating facilities' access to such LCFS programs through technical assistance.

Price greenhouse gases (GHG) emissions to incentivize their mitigation through waste reduction and organic materials management

Fugitive emissions from landfills are one of the most significant methane sources in the United States and Washington State. The state currently fails to incorporate the climate change potential of such emissions, as it still lacks a finalized statewide carbon pricing policy, such as taxes, fees, or tradable permits (Yoder, 2021). These revenue paths would further expand the industry while emphasizing more prioritized carbon reduction approaches, such as waste prevention and animal feeding (Feedback, 2020).

> *"Emphasis in coming years on undertaking climate actions will be supportive of other communities looking to improve their GHG performance through similar strategies."*
>
> *-Rich Mc McConaghan, City of Vancouver, WA*

Expand the ban of persistent herbicides such as clopyralid, aminopyralid, and picloram to include grass and crops susceptible to contaminating compost

The persistent herbicide clopyralid is a threat for composting operations, especially in eastern Washington, where it was the main reason for closing of the City of Spokane's former composting facility in Colbert in 2000 (Brunt, 2012). Although existing law prohibits the use of clopyralid in homegrown lawns, it still permits its use by certified applicators in grass and hay crops that could potentially end up in compost. When present in the compost product, herbicides have a detrimental effect on gardens, thus negatively impacting the product's demand

and adoption rate as a commodity. Composting facilities need to conduct time-consuming tests or contract with laboratories for expensive bioassays to certify that the feedstock is free of the contaminant, thus imposing an additional cost on an industry with already tight margins. Under the existing conditions, the cost of the problem is thus transferred to composting facilities (USCC, n.d.a).

The ban of clopyralid and similar products should expand to include all crops and grass susceptible to be composted, such as residential lawn, school lawns, golf courses turf, other institutional grass fields, and hay crops. Although current EPA's registration review of clopyralid improves the herbicide's labelling and communication to recipients, these measures are expected to have little to no impact on contamination problems (EPA, 2020).

Expand the existing renewable portfolio standard by setting new and more ambitious targets in the coming decades

The Energy Independence Act (EIA) established Washington's renewable portfolio standard (RPS), which requires state utilities to increase the share of renewable energy they include as part of their operations. Current targets require utilities to reach carbon neutrality by 2030, up from a 15% requirement for 2020. Other targets are needed after 2030 to ensure that only renewable energy sources feed the energy matrix. EIA goals inform the magnitude of changes required in the energy grid while also providing investors and planners with the potential demand for energy projects such as anaerobic digesters. The promotion of voluntary markets for utilities and the customers that use thermal application would benefit anaerobic digester facilities. Furthermore, the industry could also be supported by ensuring that utilities comply with existing regulations and goals from improved monitoring and enforcement from the Washington Utilities and Transport Commission (UTC) and the Federal Energy Regulatory Commission (FERC).

7.2. Improve collaboration

More collaboration is needed among the stakeholders related to organic waste management in Washington. Additional coordination through contracts and reporting would also help the system provide the required information to sustain its development. Coordination and participation can aid the expansion of the system, increased capacity to collect and process materials, strengthening of end-markets, and especially facilitation of other recommendations from this report.

A set of four specific actions is described below:

Establish a statewide working group to develop strategic policy for organic materials management

There is a large amount of knowledge held by the many stakeholders and experts around the state. On the other hand, there is also a lack of communication, understanding, and agreement between governmental bodies, industry, and other stakeholders, especially around permitting and policy design to expand diversion and organics processing (Commerce, 2020).

A statewide working group made up of the full range of organics management stakeholders working collaboratively towards a plan could move forward achievement of shared goals.

Such a plan would complement and inform climate and solid waste policy, as these topics continue to push the system's transition towards a cleaner energy mix and efficient use of materials. The working group should include service providers, facility owners, consultants, local governments, regulating agencies, end-use markets, community organizations, and environmental organizations.

Improve the availability and quality of public data related to organic materials management facilities and their operations

Data related to the operation of organic management facilities are limited, outdated, and mostly unavailable. The lack of information about operations and markets' characteristics and performance hinders efforts to incorporate it into facilities and governments' expansion plans. More available and thorough data from permitted and permit-exempt organic waste management facilities could foster development of diversion policies. Similarly, municipal planners require more information about organics management products' end-use as well as sales and product quality monitoring.

Industry and government stakeholders should identify critical information that is needed. A special study could help generate needed information, while ensuring that the use of proprietary information does not pose a risk for participating facilities.

Require municipalities to include partnered educational and outreach programs in their contracts with service providers and other collaborators to reduce contamination

Prevention (i.e., source reduction) is considered the most efficient remedy for contamination. Upstream measures like educational programs and outreach are critical to improving the quality of feedstocks received by processors. Several municipalities have implemented effective strategies by requiring, through their contracts, hauling companies to partner and collaborate in contamination prevention. The partnerships have included participating staff from the companies and constant coordination with city and county counterparts and teams. Shared responsibilities lead to increased collaboration and accountability between all parties, improved monitoring and enforcement, and increase consistency in the approaches and messages delivered to the community.

These educational programs could alternatively be run by trusted community entities. Such programs could operate with shared funding from both the local governments and haulers while taking advantage of the potential networks already served by local groups and organizations.

Establish a standing working group to define types of compostable products that composting facilities can accept, considering their capacity and type of feedstock

Currently, the materials accepted at composting facilities vary significantly, and these lists depend on the specific recipes each processor manages. Although recipes should relate to each facility's specific processes and operational conditions, there is an inconsistent approach to the type of compostable products accepted as feedstock, even among facilities with similar capacities and processed feedstock.

Compostable materials and products – both fiber-based products or compostable plastic-like products – are likely to increase and evolve. A working group with broad participation of the industry, government, and related stakeholders should be convened to define acceptable types of compostable product and make recommendations on an ongoing basis, taking into consideration the capacity and technologies of existing facilities. A similar process is underway in California through discussions and recommendations being developed by the Statewide Commission on Recycling Markets and Curbside Recycling.[26]

The recommendations may involve rejecting certain types of products and revisiting them after specific periods. This effort would bring certainty to industry participants on what changes they may or may not need to implement and inform governments about what compostable products they can or cannot incorporate into their organics collection programs. Definitions would also relate to plans for reducing contamination rates for each group, considering measures like public education campaigns, labelling clarity, and rules for marketability of products based on quality guidelines.

Recommendations should take into consideration small- and mid-scale operations and facilities processing limited types of feedstock. Decision making should also provide phase-in timeframes that allow members to adapt their operations according to their specific context and capabilities.

7.3. Expand capacity and markets

There is a current mismatch between compost and digestate supply relative to their potential demand, especially related to the agriculture sector. The state could benefit by activating markets for organics management products and thus, nurturing the industry's currently limited revenue. The introduction or expansion of equipment loan programs, voucher programs and other incentives could help address specific needs of compost and digestate production and applications. A greater variety of approaches and intervention levels is also achievable by supporting partnerships and cost-sharing, especially regarding existing infrastructure.

A set of six specific actions is described below:

Make spreading equipment readily available to farmers through equipment share and financial assistance

The adoption of compost and digestate by agricultural operations has several barriers that hamper the market's further development. Perceptions of these products as heterogeneous in composition, having unclear effectiveness, and containing contamination, lead to the preference of more standardized chemical fertilizers or alternative products. One

[26] The commission was mandated by the California Recycling Market Development Act (AB 1583, Eggman, Chapter 690, Statutes of 2019).

of the most significant barriers for adoption is the lack of spreading equipment for this type of product, which elevates the stakes of adoption for already risk-averse and financially burdened farm operators (Brady, 2019, Hills et al, 2019).

Spreading equipment could be offered through a voucher program for early adopters, by piloting the program in partnership with select organic materials management facilities willing to secure procurement for a given period. Also grants could be provided to conservation districts and similar organizations such as farms co-ops to purchase equipment that could be loaned out to or shared among farmers, expanding existing programs and starting them in other counties. Through outreach and technical assistance, these programs could provide farms with a field testing in areas of the state where compost or digestate are available for their type of agricultural production.

Incentivize the development of anaerobic digestion projects that include infrastructure cost-sharing or public-private partnerships

Developing an anaerobic digestion facility encompasses various failure risks that most agricultural operations are unwilling to take. A digester project can fail due to technical issues, the uncertain evolution of energy markets, and to a less degree, the lack of digestate demand. Although existing grants and subsidies help address these risks, the operators still hesitate to step up due to the challenges. Public-private partnerships and cost-sharing schemes allow participating parties to share the risk of failure and plan accordingly. Public procurement and end-use markets are critical for projects' success, and partnerships are effective means to incorporate both these considerations in designing the business model and related programs (Coppedge et al., 2012). Grant funding innovation and infrastructure development for organic materials management could prioritize projects presented jointly by private and public actors.

Provide funding to connect facilities producing biogas and renewable natural gas (RNG) with pipelines and the electrical grid infrastructure

Digester projects that aim to generate Renewable Natural Gas (RNG) face high costs for connecting their production with existing state natural gas pipelines (EPA, 2020n). Injection conditions also vary among different utility owners, thus increasing the uncertainty of developing the projects. Additionally, the connection is a critical step for the success of projects, as their correct operation is critical to maintaining acceptable operational standards for the entire network. California currently has a financial incentive for RNG connection equipment, with $80 million available statewide (BioCycle, 2020b).

Methane leaks are one of the most significant sources of methane emissions in the United States, so better and standardized infrastructure interconnection could help reduce these leaks. The state and its natural gas utilities would benefit from supporting projects generating RNG with the existing infrastructure, especially for use by industrial activities that cannot easily convert to electricity.

In addition, smaller biogas producers need access to the electrical grid. Biogas producers with business models based on electricity generation certified and sold for e-vehicles through LCFS programs are a novel and innovative opportunity for the industry. These producers, however, require connections to the existing electrical grid, which can be supported along with gas interconnections to pipeline infrastructure.

Incentivize and provide funding for pilot diversion strategies, such as co-digestion, that leverage existing infrastructure

Washington has incentivized co-digestion for dairy operations since the first digesters initiated their operations around 2010. Incorporating food waste has been beneficial for such operations by increasing their yields with small increases in their feedstock. The method brings technical challenges, however, as food waste streams contain higher proportions of inert materials that accumulate in the reactors. Nevertheless, co-digestion has regained attention from organic materials management leaders as it can leverage excess digester capacity in wastewater treatment plant. Pre-processing equipment prepares commercial food waste as engineered slurries for incorporation into digestion. Supporting such alternative food waste reduction methods would help diversify the system and leverage existing infrastructure. Existing private industry investments should be considered to ensure that the new facilities and processes do not financially disrupt existing industrial operations but rather expands them and leverages existing infrastructure.

Foster and support community-scale composting

Washington's organic waste management would benefit from increased development of smaller scale options such as community-based composting or campus-scaled facilities. These options generate efficiency gains by reducing the hauling of materials, thus lessening the associated impacts of nuisance odors, carbon footprint, and traffic associated with larger systems. Small-scale composting also provides an opportunity for more direct means for outreach and education around food waste prevention and odor and pest prevention, while connecting communities with the values and benefits of managing their organic materials locally.

In addition, at the residential-scale, programs like the City of Seattle's *Master Composter/Sustainability Steward Volunteer Program* and the Thurston County's *Master Recycler Composter Program* should be considerably expanded to increase their scope and impact, while incorporating them as a central piece for solid waste management planning in municipalities.

Support market expansion for organic treatment byproducts as nutrient fertilizers

Byproducts obtained from organic management operations offer an opportunity for expanding the industry revenue sources while providing valuable nutrient fertilizers for potential end-use markets. Materials like struvite, manure solids, and char have the potential to improve new customers' environmental performance while continuing the expansion of the organic materials management industry. The development of standards for these byproducts could ease their adoption in markets with high potential – such as agriculture – while orienting industry investments for their preparation. Certifications for specific uses could also foster adoption of byproducts in expanding markets, providing consumers with information about product quality and performance. More available and specific information about the application of different types of products and their differences could also speed up their adoption by new customers.

7.4. Improve performance

The performance of the organic materials management system directly depends on the training and capacity of operators at each facility as well as staff at regulatory agencies. Increased knowledge about the use of best management practices (BMPs) measured through key performance indicators could improve facilities' financial performance while reducing nuisance complaints due to mismanagement of odors generation and emissions. Furthermore, advanced training of operators and increased staff training could leverage the existing research and knowledge on the topic, whose representatives would benefit from more connection with trends and needs from the field.

A set of three specific actions is described below:

Increase the requirements for acquiring and maintaining a certificate on compost facility operation by increasing training hours and hands-on experience provided by the Washington Organic Recycling Council (WORC) and others

Washington requires supervisors of permitted composting facilities to undergo training and certificate of completion to carry out their duties. Training is also necessary for employees of permitted composting operations, which can be carried by a trained supervisor in facility operations under WAC 173-350-220(6)(vi). In our interviews with experts, however, we heard repeated suggestions that further training be required for operators of the organics management system, as facilities fail to universally incorporate best management practices into their work or experience staff turnover.

Composters could benefit from improving their management practices to significantly reduce their odors emissions and improve their products' quality while keeping processing times constant. An increase in operators' certificate requirements would allow staff to acquire additional understanding of management and technical practices' effects on facilities' performance. To reduce the burden on operators, training requirements could allow for semi in-person training settings and financial support to compensate small and medium facilities for staff training hours. Certificates may also be term-limited, requiring training on a periodic basis to update participants in the industry's most current trends, approaches, and available technology. Among other factors, consideration of this recommendation requires that training frequency and modality are designed considering the need and availability of novel methods, considerations, policies, and technology in the industry.

Update the state's manual for operating commercial composting by integrating best management practices (BMPs) based on key performance indicators (KPIs) monitoring and available technology

In 2011, Ecology published a facilities manual, *Siting and Operating Composting Facilities in Washington State Good Management Practices*. The document describes the regulatory framework for operating a facility in the state and advises on the good management practices for improving facilities' performance. The document was last updated was in 2013 (Ecology, 2013a), and the document was mentioned by some interviewees as being out of date. A manual update could emphasize better incorporation of best management practices (BMPs) that are specific to facilities operations as described in their operations plans. Monitoring would focus on maintaining key performance indicators (KPIs) within the ranges that reflect BMPs specific to facilities' operations. Experience and research have demonstrated that facilities can address typical problems that arise from mismanagement. A review of available technology for composting processes, contamination prevention/removal, and feedstock sizing could also benefit composters scaling up their operations or including new organic materials, especially food waste.

Consider using excess steam from industrial and energy sources to treat organic waste collected in urban areas prior to transport east

A particular yet significant improvement for the industry would be the ability to treat green waste (yard debris and agricultural organics) to allow it to be transported through apple maggot quarantine areas. Heat treatment (per WAC 16-470-124) can make it possible for this type of waste to be transported from quarantined areas (i.e., urbanized western Washington) to pest-free areas in agriculture-rich eastern Washington. Such treatment is expensive as a stand-alone operation. Steam from utilities (e.g., wastewater treatment and electrical generation) and some industrial facilities (e.g., manufacturing waste management, forestry and wood) or other sources could signify an opportunity under an industrial symbiosis approach (Light House, 2019).

A feasibility study could assess the economic and technical viability of steam projects and determine potential integration with singular entities' business models for expanding markets to the east. Industrial areas in large urban settings could generate excess steam could treat green waste of facilities nearby. The study would assess how benefits from exploiting available steam compensate for extra costs such as piping infrastructure needed for maintaining high temperatures in piles for a long period of time.

7.5. Revise permitting

The regulation of organic materials management facilities protects communities and environmental health. These regulations focus on air and water emissions, public health monitoring, and operational standards.

Regulations of volatile organic compounds appear to be creating challenges for industry expansion. The permitting process is generally perceived by interviewees as excessively lengthy and overly complex. In particular, air quality regulation was often criticized because of inconsistent approaches to permitting and monitoring, lack of data, and over-reliance on California standards (which are not reflective of Washington's feedstocks and climate conditions). In addition, longstanding conflicts with neighbors over odor complaints continue to be a significant issue. These conflicts damage the credibility of the industry and make it more difficult to site new facilities.

A set of six specific actions is described below:

Manage the permitting of solid organic waste management facilities by creating a coordinated process

The permitting process for siting a facility in Washington is complicated and lengthy, which is appropriate, at least in part, to ensure environmental and community protection. Currently, project developers and facility operators must interact with multiple agencies with limited coordination among them. Small jurisdictions' regulatory staff are overburdened and are generalists who oversee and inspect a large range of types of facilities, from auto shops to compost facilities. Some industry interviewees reported that they often must train the regulators in compost basics.

The regulatory process is information-intensive, with multiple parties to whom facilities report. This results in regulations that are interpreted differently in different jurisdictions, uncertainty for operators, and delays. There is a need for revising the process by creating a coordinated permitting process. There are only a limited number of facilities (currently 65 permitted facilities) and thus staff could work in coordination to manage regulation of these facilities. This approach could improve communication and consistency while reducing paperwork and iterations for developers. One potential approach could be to consolidate permit issuance in Ecology rather than in local health districts, which would off-load burdened county health departments.

The creation of the coordinated permitting process should ensure that all stakeholders interests are included and considered, including neighboring property owners and communities. It should also be noted that some agencies such as Ecology have multiple roles (e.g., solid waste management, air quality) that are managed by different parts of the agency. These programs can have different goals and mandates.

Redesign permitting for composting facilities based on key performance indicator (KPI) ranges according to facility operations plans

Creating and implementing key performance indicators (KPI) in the organic materials management industry could significantly improve the industry's environmental and economic performance. Key performance indicators (KPI) include temperature, oxygen levels, and moisture which are reflective of the aerobic digestion process in composting piles.

Regulation of facilities, per WAC 173-350-220, establishes general limits for retention times and temperature measurements. Laboratory results are also required for finished compost on a 5,000 cubic yards basis. Several interviewees, however, noted that regulators and facilities would benefit by focusing regulation more on monitoring operational conditions measured through KPIs than on requirements that are often perceived as too prescriptive and not based on science. Facilities' operations plans provide detailed information about their throughput, retention times, location, and planned strategies and investments to capture and control emissions. Regulators could take this information to define KPI ranges for temperature, oxygen, pH, C/N ratios, moisture content, and density that can be monitored for compliance of both facility design parameters and environmental performance. KPIs are easily measured by facility staff.

As defined and approved in facilities' operations plans, the amount of material being input and processed has a significant effect on emissions and operational condition standards may not be sufficient alone to eliminate impacts. A combination of design of the emission source, the emissions capture systems, emission controls, and operational monitoring standards that minimize emissions are keys to operational success. Such plans and their associated monitoring could help assess manufacturers' capability of managing large quantities of complex streams such like food waste and provide tangible evidence when its incorporation fails to adhere design parameters and lead to potential nuisance.

Agencies could develop and pilot the new system under the current enforcement standards and later adjust for needed modifications. The participation of industry, academic and consulting experts, and composting organizations are critical for informing the design of the new system.

Establish standards for VOC emissions testing methods required for composting operations to establish compliance with air quality permitting requirements

Composting facilities processing large quantities of feedstock in Washington want to demonstrate that their operations do not surpass volatile organic compounds (VOC) emissions that can trigger costly and complex Title V requirements (i.e., additional testing and limited throughput), unless they truly are at those thresholds. There are two main methods to estimate these emissions, either by modeling using emission factors or by direct sampling. The first method currently relies on California data that, according to interviewees, fails to account for local conditions and incorporate abatement methods, thus mis-characterizing critical factors for the emissions rate expected from a facility. On the other hand, the currently accepted sampling methods are considered inflexible, expensive, and unreliable, as they focus on single samples covering operations in large and heterogeneous areas.

There is a need to collect data to create a local database of facilities' emissions, adding to the existing parameters information on meteorological conditions, abatement methods, and type of feedstock. A broader set of sampling methods would allow facilities to select approaches that potentially reflect their emissions more effectively (Brown et al., 2020b). This effort should be guided by a task force including regulatory entities, academia, and the industry to ensure that testing methods and their protocols prioritize monitoring of operational conditions over these more complex and expensive methods.

Define standardized measurement methods for detecting odors emitted by organic waste management facilities

Nuisance caused by odors is one of the main complaints related to organic management facilities and one of the main reasons for failing operations. Odors are complex emissions, as they are caused by minimal concentrations of volatile compounds subject to quick changes of weather and certain operational processes. Interviewees indicated a lack of consistency in measuring these emissions and an overreliance on compliance as an indicator of operational performance. Some agencies have taken nuisance odor enforcement actions which have been sustained through appeals. Different measurement techniques may be challenged by nearby residents in that they believe the data denies the existence of real impacts on individuals.

It would be beneficial for regulatory agencies to improve the consistency of methods and generate a set of rules and options for monitoring and enforcing air quality standards related to odors. With more precise rules, agencies could share monitoring indicators with the regulated parties, who could then work to address the issue proactively. Agencies could, for example, agree on a list of applicable standards for measuring and modelling odor flux, like the ISO and ASTM standards. It could be beneficial to prioritize cost-effective approaches to monitoring over the reliance on odor flux measurements. Research has connected operational conditions in composting facilities to odor flux which can make monitoring based on KPIs a first approach to consider.

Proactively define zoning for the development of organic materials management facilities

Land use zoning is one of the most significant barriers to the development of organic waste management facilities and does not reflect the desire of many community members to compost. The lack of zoning increases projects' uncertainty and restricts the potential demand for this type of activity in a region (Sandson et al., 2019). A proactive approach would suggest that municipalities actively search for space suitable for the activity in consideration of logistical, geotechnical, and meteorological conditions. Ideally, these sites would be co-located with transfer stations, landfills, or industrial uses, ensuring that approved zones do not abut residential or other incompatible users through buffer zones.

County administrations could lead the definition process in coordination with municipalities as facilities often operate within their limits. These entities could integrate the definition process into comprehensive solid waste management planning processes. The United States Composting Council is currently developing a model zoning ordinance with regulations differentiated by facility type (on-farm, small scale and large facilities) and definitions of composting concepts, land use categories, and permit types (USCC, n.d.b). Local governments and agencies in Washington could adopt all or parts of this model.

Increase funding for professional training and monitoring equipment at regulatory agencies

The regulation of the organic materials management industry can only be as effective as those carrying it out. Our interviews highlighted a need to increase regulating agency staff's understanding of organic materials management operations' characteristics in many locations or a need for more staff who are dedicated to this topic, both of which would depend on increased funding. Although the organics management sector is only a fraction of agencies' vast duties, the degree of agreement we heard about the need for staff training is concerning. An annual online and field-based training for staff working in the field of organics management could help address the gap. This training could be conducted by, for example, the Washington Organic Recycling Council, the U.S. Composting Council, and the Solid Waste Association of America. Also, once standard measurement methods are defined, agencies could acquire the equipment necessary for improving detection of emissions.

7.6. Support innovation

Washington is one of the most prominent leaders of operational organic management systems nationwide. Some of its companies are globally recognized for their constant innovation in the field. The state could nurture this leadership and support development of methods and technologies to help address current gaps in organic materials management. Grants could address specific issues like the operation of more cost-efficient programs or solutions for isolated and low-density areas. Funding is also necessary to expand and improve the existing infrastructure to fully incorporate complex materials like food waste and support the diversification of alternatives for dealing with the issue.

A set of five specific actions is described below:

Encourage the development of organic management systems for highly localized anaerobic digesters, in-vessel composting, vermicomposting, effective microorganisms, and bokashi composting operations

Small scale organics management operations are suitable onsite organic waste management programs and for areas with low population density or that are logistically challenging for more standard operations (e.g., islands). On-site composting can reduce emissions footprint and create local value (and jobs) compared to bigger and remote operations.

The state could benefit from supporting the implementation of these solutions by piloting specific projects while simultaneously developing the technology for its replication elsewhere. Innovative methods include small-scale anaerobic digestion, in-vessel composting, vermicomposting, and effective microorganisms and bokashi composting system, fermenting, among others. Businesses have exhibited openness to pilot back-of-house approaches for small-scale composting and anaerobic digestion which could, in turn, help create momentum elsewhere.

Attention must be paid to the business models for these small-scale operations. Some past initiatives based on small-scale operations have failed due to human limitations and lack of scale. As these processes require trained staff to operate them, some level of scale is necessary to allow them, for example, to manage more than one facility. Business models based on specialized services for operating these facilities or program staff trained for operating multiple locations in commercial settings could be explored.

Provide funding to build, modify, or expand organic materials management facilities that can process food scraps

Food scraps are a significant source of methane emissions when disposed in landfills. They are also challenging materials to process in organics management facilities because they can generate odors and bring along significant contamination problems (i.e., plastics). Nevertheless, food waste is a highly nutritious feedstock. Most composting facilities can handle this waste stream if they implement changes to their process and practices. These changes require operators to invest in facility redesign and construction, acquisition of equipment, modification of process parameters, and staff training. The state should support those facilities willing to include food waste into their operations, mostly small and medium-scale facilities whose financial status cannot support such expense. The support could consist of low-interest rate loans or grants to cover the investments.

Provide incentives for anaerobic digestion projects such as co-digestion (farm-based and WWTPs) and high-solid anaerobic digesters

Washington has a significant potential for the development of anaerobic digestion. Digesters' products can be used as fertilizers and their biogas production converted to electricity for electromobility and renewable natural gas for specific uses. Additionally, once operative, digesters can operate close to carbon neutrality and, in some farm-based digesters, achieve carbon-negative emissions (EPA, 2020). The growth of digesters has stagnated in the state, and more support is needed to expand the industry.

The Department of Commerce should continue to support the development of farm-based digesters and target large volumes of food waste generated by cities to minimize its burden on the composting system. The approach to such investment should consider high solids anaerobic digestion and co-digestion performed in farms, dairies, and wastewater treatment facilities. The state would benefit from supporting the recently federally funded Washington State University-led project to identify new locations for anaerobic digesters (EPA, 2020p).

Anaerobic digestion projects, as well the whole organic waste management industry, is susceptible to the impact of contamination on their products and costs. Business models must consider this factor in a way that revenue from sales and government incentives compensate for operational costs. The manufacturers, hauling companies, local governments and communities continue to work towards cleaner feedstocks Nevertheless, continued support of this industry is necessary as a means to develop a diversified and resilient organic waste management system that can also help further reduce GHG emissions.

Provide funding for expansion of the purchase of products generated through organic management, e.g., through coupons or similar mechanisms

Organics products have not deeply penetrated agricultural soil amendment and fertilizer markets and continue to be mostly consumed by landscapers. Vast potential still exists in the state, as compost and digestate could be integrated into many agricultural operations, both organic and conventional. One way to incentivize the market is by offering a coupon program or grants that connect interested parties with producers. The mechanism would reduce producers' uncertainty by providing them with a known demand for their products. At the same time, consumers could benefit from lower prices and a third-party verification process linked to the program (e.g., coupons or similar), and of the product quality.

Create an innovation center (or add to an existing center) for the development and piloting of technologies in organic materials management

Long-term funding is necessary to expand the State's innovation ecosystem capacity for developing and piloting new technologies in organic materials management. Currently, the Washington State University, the United States Department of Agriculture, and the University of Washington are the local institutions with the largest research and development capacities.

Washington could follow the model of the San Francisco Bay Area waste innovation ecosystem. This innovation center includes the USDA's Agricultural Research Service in Albany, DOE's Advanced Biofuels Development Unit and Joint Bioenergy Institute, and the UC Berkeley labs.

Such an innovation center could leverage the existing agricultural research laboratories throughout the state, research expertise, and capacity to attract funding. The initiative would bring the necessary continuity to existing efforts, while creating additional expertise through consistent staff with long-term knowledge, focus, and hands-on experience.

7.7. Improve standards

The composting and anaerobic digestion industry lack some standards that could improve their performance and allow them to operate more efficiently. Certain operational conditions should be defined statewide to help reduce contamination and emissions derived from the industry. Similarly, standards for utilizing the industry's generated energy, soil amendments, and fertilizers could increase its demand and further expand the industry's development.

A set of three specific actions is described below:

Update the existing list of chemical contaminants and their permitted levels in organics management products, potentially adding PFAS to the list

Organic management operations must certify that contaminants in their products do not exceed standards (WAC 173-350-220, table 220-B Testing Parameters). The existing list of parameters and levels were generally accepted by industry interviewees and considered safe for the population, although we also heard concerns from others about specific contaminants. In light of this, there should be a mandate to check the relevance of the current restrictions to ensure that toxic chemicals are being addressed. The review process should be replicated periodically over time.

The inclusion of emergent contaminants like perfluorooctanoic acid substances (PFAS) should be included in the review. Such chemicals are usually found in food packaging and paper products and can cause persistent effects when incorporated into the soil and food streams through compost products.

A complementary approach would be bans on the use of chemicals in products that enter the organic waste management systems in large quantities. For example, recent legislation (70A.222.070 RCW) bans PFAS in packaging. A PFAS Chemical Action Plan (CAP) underway addresses PFAS in compost specifically (ECY, 2020c).

Require compostable foodservice products to be distinctly colored (green/brown coloration) and labeled so that they can be easily distinguished if allowed at facilities

Compostable film bags and foodservice products have the potential to increase diversion rates of food scraps from landfills, thus representing an opportunity for expanding the organic materials management industry. Their inclusion in organic feedstock, however, often poses operational challenges and does not add to compost nutrient quality other than the associated remnant food scraps. Operational challenges include additional retention times for processing, machinery clogging, and litter generation when mismanaged. Proper equipment and management practices can address such challenges, although clearer product differentiation would significantly improve manufacturers' ability to reduce contamination from non-compostable products.

Washington regulations aim to reduce contamination in organics management operations by banning products marketed as biodegradable and requiring that compostable products meet the American Society for Testing and Materials (ASTM) standards (RCW 70A.455.050). These mandates, however, do not require visual differentiation through colors for products other than for bags, nor a distinction for look-alike plastic products. The regulation should be amended to require differentiation based on colors for all compostable plastic products.

Fiber-based compostable products are preferrable to bioplastics and are more accepted as feedstock because of their higher value for compost and by posing fewer operational issues. Although clear differentiation would improve sorting out non-compostable plastic products from processing, diversion programs and manufacturing would nonetheless benefit from de-emphasizing bioplastic products from their outreach campaigns.

Set standards and requirements for the application of digestate products in the state

Digestate from anaerobic digestion, if processed, is useful as a fertilizer in agriculture and landscaping. Digester byproducts' adoption, however, has not expanded significantly for various reasons, including the lack of standards for their application. This gap precludes the use of the product by early adopters who have difficulties comparing features and differences of various digestates as well as ascertaining how they compare to conventional products. In this sense, the transaction costs and information asymmetry become a barrier to further expanding the market. The state could benefit from setting standards for digestate products since they could help drive down carbon emissions and offer a competitive option for isolated areas in the state.

7.8. Improve contractual processes

Contracts are a vital component of organics management as they provide certainty for long-term revenue and feedstock streams, which are vital for the sustainability of businesses. Long-term contracts also provide governments with certainty about their solid waste management system plans while increasing trust between them and partner institutions. The standardization of contracting processes, the alignment of collection systems with waste reduction, and the incentivization of renewable fuels are part of improving these contractual processes.

A set of four specific actions is described below:

Regionally standardize local governments contracting processes with organic materials management facilities

The purchasing power of governmental agencies across the state is a considerable market force. State agencies and local governments with their public works, parks, and transportation departments offer a potential for organics processing markets expansion. Washington's 43.19A.120 RCW encourages local governments to purchase compost from facilities processing their organic waste streams.

Bioretention soil, a blend of compost and sand, is used in green infrastructure projects. Research from WSU shows that filtering polluted stormwater through this media can reduce mortality and harm to salmon and other aquatic species (WSU, 2015). Thus, green stormwater infrastructure using compost is a potentially large, and untapped end market.

There is a need, however, for greater coordination between jurisdictions and the organic materials hauling companies and processing facilities. The lack of coordination is reflected in contracts that differ in requirements and standards, which leads to inefficiencies in negotiations and inconsistency between organics management programs. The coordination problems can also lead to customer confusion and negatively impact facilities' operations. Ecology could work with others towards the establishment of regional standards for contracting processes like the ones created in King and Clark counties. Standardized contracts should be locally defined and attend to the jurisdictions' varied needs and context while providing safe public procurement and collection for municipalities. One suggested approach is to use the contacting to direct all organic waste collected within the same jurisdiction. Like landfill rates, counties could develop organic waste processing rates for organic solid waste through a transparent valuation process as currently done in King County in their Interlocal Agreements. This approach could provide stability for processors, transparency to rate payers for costs, and consistent standards.

Encourage municipalities to pilot Pay-As-You-Throw (PAYT) collection systems based on weight instead of volume for commercial collection

Pay-As-You-Throw (PAYT) revenue systems are an effective means of incentivizing waste reduction. These systems, however, have contributed to defunding public support for compost operations, given the associated (and positive) reduction of garbage collected and its corresponding revenue for the overall solid waste management system. As collection and processing costs are mostly related to collected materials' weight, it is advisable to associate PAYT systems with this variable.

As opposed to the residential collection, the waste organics collected in commercial establishments can be weighed and charged accordingly. By doing so, businesses receive an incentive to reduce their waste volume and better manage their processes to avoid it. Businesses could achieve significant savings in utility bills by performing these changes and expanding such behavior could have a broad impact on the organic waste collection system. Weight-based PAYT should be evaluated and considered in regional contracting as critical drivers of waste reduction. The assessment should consider factors that make this approach feasible such like carts and front/rear load dumpsters availability and the required investment, among others.

Set bid preferences for renewable fuels like renewable natural gas in government contracts for heavy duty vehicles

Renewable natural gas (RNG) and electromobility offer an opportunity for carbon emission reductions, especially for heavy-duty vehicles. Local governments would benefit from setting bid preferences to foster the adoption of renewable sources for their fleets. Rather than focus on a sole type of energy, governments should base their priorities on variables such as cost-efficiency, reliability, and available infrastructure. In this sense, renewable natural gas could be a competitive energy source for certain operations that cannot easily electrify.

Implement better systems of source separation through incentives and sanctions

Waste separation efficiency increases with upstream measures. While there has been significant effort between hauling companies and local governments to prevent contamination, there is room for more coordinated collaboration to address contamination rates in incoming feedstock. Approaches to this issue include collaborative outreach initiatives and "rejection" policies in municipal contracts, among others.

A statewide approach to the issue could further incent a proactive role for hauling companies to reduce contamination while penalizing those who persistently fail to tackle the problem. Incentives could include grants, loans, or tax breaks for initiatives aiming to reduce current contamination levels through, for example, technology acquisition, innovation, and outreach. A sanctions scheme could be designed to encourage early corrections from haulers, with increasingly higher fines in case of noncompliance.

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Appendices

Appendix 1: Washington State regions

Washington State regions and their corresponding counties:

Central	Eastern	Northwest	Southwest
Benton	Adams	Island	Clallam
Chelan	Asotin	King	Clark
Douglas	Columbia	Kitsap	Cowlitz
Kittitas	Ferry	San Juan	Grays Harbor
Klickitat	Franklin	Skagit	Jefferson
Okanogan	Garfield	Snohomish	Lewis
Yakima	Grant	Whatcom	Mason
	Lincoln		Pacific
	Pend Oreille		Pierce
	Spokane		Skamania
	Stevens		Thurston
	Walla Walla		Wahkiakum
	Whitman		

Washington State regions as defined by Ecology:

Source: Ecology (n.d.f)

Appendix 2: Characterization of facilities

Number of facilities represented by industry interviewees, by region and processed volume in 2018 (in tons):

Region	>50,000	> 10,000 - 50,000	> 1,000 - 10,000	> 0 - 1,000	Total
Northwest	1	0	2	5	**8**
Southwest	2	2	2	3	**9**
Central	0	1	1	0	**2**
Eastern	0	1	1	0	**2**
Total	**3**	**4**	**6**	**8**	**21**

Appendix 3: Characterization of interviewees

Number of non-industry interviewees by expertise and region:

Field of expertise or knowledge	North west	South west	Central	Eastern	State wide	Out of state	Total
Academic research Includes: Bio systems, Economics, Soil, and Organics					5		5
Capacity building Includes: Infrastructure engineering consultancy and Compost Manufacturing Alliance					7		7
Counties and Municipalities Includes: Organics, Permitting and Solid Waste	3	3		2			8
Industry Includes: Haulers, Vermiculture, Anaerobic Digestion, and Co-digestion		1		2	3	1	7
Permitting Includes: Clean Air Agency	2*				1		3
Washington state agencies Includes: WSDA Dairy, Organics, Pest Program; WSDOT, and Ecology	1				6		7
Total	6	4	0	4	22	1	37

* The Northwest region category contains an agency that is located on the periphery and oversees the Puget Sound area.

Appendix 4: Industrial composting facilities in Washington (2018)

Permitted industrial composting facilities that operated in 2018, by region and type:

Region	Biosolids management	Compost Facility	Compost Facility (Exempt)	Total
Central	1	7	1	9
Eastern		11	1	12
Northwest	6	15	4	25
Southwest	3	11	5	19
Total	10	44	11	65

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Per WAC 173-350-220, several categories of exempt facilities do not report to Ecology and are not included in this table.

Facilities that operated in Washington State during 2018 required to report to Ecology under WAC 173-350-220:

County	Facility Name	Permit status	Processing capacity (max. throughput)	Site capacity (max. capacity on-site)
Benton	City of Richland Horn Rapids Composting	Biosolids management	N/A	N/A
Chelan	Stemilt World Famous Compost Facility			N/A
Clallam	City of Port Angeles Compost Facility	Permitted	5,350 tons	9,300 cubic yards
Clark	H & H Wood Recyclers	Permitted	10,000 tons	30,000 tons
Columbia	Columbia Compost*	Biosolids management	N/A	N/A
Cowlitz	Cowlitz Valley Compost	Exempt	~34,000 tons per year	40,500 cubic yards
Franklin	Lamb Weston Inc. Static Aerated Compost Facility	Exempt - Land Application	N/A	N/A
	Mesa Compost Facility	Exempt	N/A	N/A
	Coyote Ridge Correction Center	Exempt	N/A	1,000 cubic yards
Grant	Royal Organic Products	Permitted		547,500 cubic yards
	Quincy Compost	Permitted		N/A
	Lawrence Farms LLC Compost Facility	Exempt		N/A

County	Facility Name	Permit status	Processing capacity (max. throughput)	Site capacity (max. capacity on-site)
	Ovenell Farms Composting Facility	Permitted	257,000 tons	50,000 tons (205,000 cubic yards)
Grays Harbor	Stafford Creek Corrections Center	Exempt	N/A	N/A
Island	Wildwood Farm LLC	Exempt	N/A	N/A
	Mailliard's Landing Nursery	Permitted	N/A	N/A
Jefferson	Shorts Family Farm	Exempt	N/A	N/A
	City of Port Townsend Compost Facility	Permitted - Biosolids management		N/A
King	Cedar Grove Composting Co. Maple Valley	Permitted	250,000 tons	780,000 cubic yards
	UW Seattle Campus Compost Facility	Exempt	N/A	N/A
	Seattle University Onsite Composting	Exempt	N/A	N/A
	Woodland Park Zoo	Exempt	N/A	N/A
	Steerco/Sawdust Supply	Permitted	15,500 cubic yards	31,500 cubic yards which includes up to 16,000 cubic yards of finished compost
Kitsap	Olympic Organics LLC	Permitted	N/A	35,000 tons
Kittitas	Kittitas County Compost Facility	Permitted	N/A	6,000 tons
Klickitat	Dirt Hugger LLC	Permitted		64,000 tons
Lewis	Centralia Composting	Exempt	N/A	N/A
Lincoln	Barr-Tech Composting Facility**	Biosolids management / Permitted	N/A	N/A
Mason	Washington Corrections Center Composting Facility		4,000 tons per day	N/A
	North Mason Fiber Co.		48,000 tons per year	105,000 cubic yards
Pierce	Washington Corrections Center for Women Compost Facility	Exempt	N/A	N/A
	Wilcox Farms Inc	Exempt	N/A	N/A
	Green Pet Compost Company, LLC	Exempt	N/A	N/A

County	Facility Name	Permit status	Processing capacity (max. throughput)	Site capacity (max. capacity on-site)
	JBLM PCSS Storage + Treatment Facility & Composting Facility	Permitted		6,000 tons
	Pierce County (Purdy) Composting Facility	Permitted	N/A	70,000 a year
	LRI Compost Factory	Permitted	N/A	325 tons per day
San Juan	Midnight's Farm	Exempt	N/A	N/A
Skagit	Dykstra Farm	Permitted	9,000 cubic yards	1,000 cubic yards at any one time
	Skagit Soils Inc	Permitted	26,000 cubic yards annually	11,000 cubic yards at any one time
Snohomish	Lenz Enterprises Inc	Permitted	N/A	75,000 tons
	Pacific Topsoils - Maltby	Permitted	N/A	53,333 tons
	Full Circle Natural Products Inc.	Exempt	N/A	N/A
	Riverside Topsoil Inc	Permitted	N/A	15,000 tons
	Bailand Farms Yardwaste (Bailey) Compost	Permitted	N/A	30,000 tons
	Thomas Farm Agricultural Composting	Exempt	N/A	N/A
	Cedar Grove Composting, Inc.	Permitted		228,000 tons
Spokane	Cheney WWTP & Compost Facility*	Biosolids management	N/A	N/A
Thurston	Cedar Creek Corrections Center*	Exempt	N/A	N/A
	Silver Springs Organics Composting LLC	Permitted	N/A	125,000 tons
Walla Walla	Sudbury Landfill Compost Facility		N/A	N/A
	Boise White Paper LLC		N/A	N/A
Whatcom	Smit's Compost	Exempt	N/A	N/A
	Green Earth Technology (Compost)		N/A	N/A
Whitman	WSU Compost Facility	Permitted	N/A	80,000 tons
Yakima	Apple tree resort	Exempt		Exempt
	Colonial Lawn & Garden Inc	Exempt		Exempt
	Sunnyside Dairy	Exempt		Exempt
	Natural Selection Farms Composting Facility	Permitted	N/A	161 cubic yards

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b).

** Facilities permitted under compost rules (WAC 173-350-220) and biosolids rules (WAC 173-308-170)

Number and processed volume (in tons) of facilities that operated in Washington State in 2018 required to report to Ecology under WAC 173-350-220, by region and county

Region and County	Number of facilities	Volume Processed [tons]
Central	**8**	**143,777**
Benton	1	11,350
Chelan	1	12,530
Kittitas	1	2,658
Klickitat	1	38,947
Yakima	4	78,292
Eastern	**12**	**201,272**
Adams	1	7,286
Columbia	1	186
Franklin	2	23
Grant	3	44,041
Lincoln	1	84,251
Spokane	1	2,885
Walla Walla	2	61,020
Whitman	1	1,580
Northwest	**19**	**617,730**
Island	2	2,706
King	5	241,738
Kitsap	1	7,765
San Juan	1	395
Skagit	2	7,996
Snohomish	6	326,421
Whatcom	2	30,709
Southwest	**16**	**303,998**
Clallam	1	3,727
Clark	1	624
Cowlitz	1	18,027
Grays Harbor	1	364
Jefferson	2	4,775
Lewis	1	17
Mason	2	12,237
Pierce	5	202,325
Thurston	2	61,902
Total	**55**	**1,266,777**

Number of facilities that operated in Washington State in 2018 and were required to report to Ecology under WAC 173-350-220, by composting method and region:

Composting Method	Central	Eastern	Northwest	Southwest
Turned windrow	6	7	8	2
Aerated turned mass bed	1			4
Actively aerated static pile	2	5	8	7
Passively aerated static pile		2	1	2
In-vessel (containerized)		1	3	4
Other	1	1	1	

Table related to 55 composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the table. Row and column totals do not reflect the total number of facilities as 11 of them use more than one composting method.

Number of facilities that operated in Washington State in 2018 required to report to Ecology under WAC 173-350-220, by volume processed (in tons) and region:

Volume Processed (tons)	Central	Eastern	Northwest	Southwest	Total
> 0 - 1,000	2	4	6	7	**19**
> 1,000 - 10,000	1	5	6	4	**16**
> 10,000 - 50,000	5	1	3	3	**12**
> 50,000 - 100,000		2	2	1	**5**
> 100,000			2	1	**3**
Total	**8**	**12**	**19**	**16**	**55**

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the table

Volume of organic material feedstock provided for industrial composting facilities that operated in 2018 required to report to Ecology under WA 173-350-220, by type of material, region, and county:

County and Region	Mixed Yard Debris and Food waste	Yard Debris Only	Manure and bedding	Food Processing Waste (Pre-Consumer)	Food Waste (Post-Consumer)	Total Food Waste*	Other Feedstock	Total
Central		21,777.3	26,921.6	45,980.7	21.4	46,002.1	10,276.6	104,977.5
Benton		10,501.0	137.3	2,306.0		2,306.0	849.0	13,793.3
Chelan		7,418.9	1,761.3	3,549.1		3,549.1	-	12,729.3
Douglas		42.6				-	-	42.6
Kittitas		2,634.9	23.0	1,291.0		1,291.0	-	3,948.9
Klickitat		478.0		534.0		534.0	2.0	1,014.0
Okanogan				738.0		738.0	-	738.0
Yakima		701.8	25,000.0	37,562.5	21.4	37,583.9	9,425.6	72,711.3
Eastern	60,377.6	12,072.4	23,046.3	25,078.0	261.6	85,717.2	78,375.6	199,211.5
Adams						-	472.7	472.7
Columbia		83.2				-	8.0	91.2
Franklin	1.6	1,922.4		127.6		129.2	1.4	2,052.9
Garfield						-	95.3	95.3
Grant		1,170.3	22,941.1	4,977.9		4,977.9	21,080.2	50,169.4
Lincoln	143.0	75.3				143.0	332.0	550.3
Pend Oreille						-	71.8	71.8
Spokane	60,233.0	2,885.0				60,233.0	19,974.2	83,092.2
Walla Walla		5,936.3	25.8	19,907.1		19,907.1	35,150.8	61,020.0
Whitman			79.5	65.4	261.6	327.0	1,189.3	1,595.8
Northwest	360,024.0	123,966.5	23,995.6	1,188.2	61,887.8	423,100.1	53,712.7	624,774.9
Island		2,227.7	218.7			-	259.2	2,705.6
King	241,360.0	63,975.2	3,822.1	120.2	49,655.8	291,136.0	13,817.5	372,750.8
Kitsap		9,211.0		425.0		425.0	288.0	9,924.0
San Juan		110.2	255.2			-	29.7	395.1
Skagit	6,553.0	185.3	583.2	36.0		6,589.0	674.2	8,031.7
Snohomish	102,925.0	37,504.1	15,126.1		11,331.0	114,256.0	33,372.1	200,258.3
Whatcom	9,186.0	10,753.0	3,990.4	607.0	901.0	10,694.0	5,272.0	30,709.4
Southwest	27,857.0	254,891.3	1,732.5	1,026.0	1,321.6	30,204.6	7,288.0	294,116.4
Clallam		2,831.0		499.0		499.0	525.2	3,855.2
Clark	5,555.0	7,581.0				5,555.0	-	13,136.0
Grays					134.0	134.0	230.1	364.1
Jefferson		3,711.7	425.0			-	403.3	4,540.0
Lewis		1,979.1				-	-	1,979.1
Mason		181.0			161.0	161.0	199.2	541.3
Pierce		238,607.2	1,307.5	110.0	947.9	1,057.9	2,615.5	243,588.0
Skamania						-	5.0	5.0
Thurston	22,302.0	0.3		417.0	78.8	22,797.8	3,309.7	26,107.7
Out-of-state	17,742.0	12,465.0	80.0	6,396.0	30.0	24,168.0	6,983.8	43,696.8
Total	466,000.6	425,172.5	75,776.0	79,668.9	63,522.5	1,194,216.0	306,289.4	1,266,777.0

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the table. Total food waste includes the following types of material: Food processing waste (pre-consumer), food waste (post-consumer), and mixed yard debris and food waste.

Types of materials processed by industrial composting facilities during 2018 in Washington State, required to report to Ecology under WAC 173-350-220, by county and region

County and Region	Agricultural organics (vegetative)	Biosolids, dry	Food processing waste (pre-consumer)	Food waste (post-consumer)	Industrial organics	Land clearing debris	Manure and bedding	Mortalities and other animal parts	Sawdust / shavings	Wood waste	Mixed Yard debris/Food waste	Yard debris	Paper (mixed)
Central	X	X	X	X		X	X		X	X	X	X	
Benton		X								X		X	
Chelan			X				X					X	
Kittitas							X					X	
Klickitat	X		X	X		X				X	X	X	
Yakima	X		X	X			X		X	X		X	
Eastern	X	X	X	X	X		X	X	X	X	X	X	
Adams	X						X	X		X		X	
Columbia		X			X							X	
Franklin										X	X	X	
Grant	X		X				X			X		X	
Lincoln	X	X	X		X				X	X	X		
Spokane												X	
Walla Walla	X				X		X	X		X		X	
Whitman	X		X	X			X	X		X			
Northwest	X		X	X		X	X	X	X	X	X	X	X
Island						X	X					X	
King			X	X		X	X		X	X	X	X	X
Kitsap			X				X				X	X	
San Juan	X						X	X				X	
Skagit	X						X				X	X	
Snohomish	X			X		X	X		X	X	X	X	
Whatcom			X	X		X	X		X		X	X	
Southwest	X	X	X	X		X	X		X	X	X	X	
Clallam		X										X	
Clark												X	
Cowlitz												X	
Grays Harbor				X						X			
Jefferson	X	X					X		X			X	
Lewis												X	
Mason			X	X		X				X		X	
Pierce			X	X		X	X		X	X		X	
Thurston	X	X		X						X	X	X	

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b) Facilities processing biosolids associated with wastewater treatment plants are not included in the table.

Change between 2016 and 2018 in processed volume of organic materials (in tons) received by industrial composting facilities, required to report to Ecology under WAC 173-350-220, by county and type of material:

County and Region	Mixed Yard Debris and Food waste	Yard Debris Only	Manure and bedding	Food Processing Waste (Pre-Consumer)	Food Waste (Post-Consumer)	Total Food Waste (*)	Other Feedstock	Total
Central	**10,703.6**	**10,934.8**	**3,803.9**	**20,130.7**	**(48.4)**	**30,785.9**	**(1,543.5)**	**43,981.1**
Benton	-	10,501.0	-	-	-	-	849.0	11,350.0
Chelan	-	(3,013.5)	836.9	(4,599.2)	-	(4,599.2)	(2,200.0)	(8,975.8)
Kittitas	-	(89.1)	(33.0)	-	-	-	-	(122.1)
Klickitat	10,703.6	4,051.0	-	4,839.3	(69.8)	15,473.1	(1,459.1)	18,065.1
Yakima	-	(514.6)	3,000.0	19,890.6	21.4	19,912.0	1,266.6	23,664.0
Eastern	**(35,101.4)**	**4,176.5**	**(2,684.3)**	**(13,222.4)**	**14.7**	**(50,061.1)**	**7,939.5**	**(40,629.4)**
Adams	-	(537.9)	(7,167.7)	-	-	-	(11,977.7)	(19,683.3)
Columbia	-	23.2	(50.0)	-	-	-	15.3	(11.5)
Franklin	1.6	20.0	-	-	-	1.6	1.4	23.0
Grant	-	(123.9)	14,262.4	2,293.9	-	2,293.9	16,219.6	32,652.0
Lincoln	(35,103.0)	(88.0)	-	1,628.0	-	(35,227.0)	(16,187.0)	(51,502.0)
Spokane	-	2,885.0	-	-	-	-	-	2,885.0
Walla Walla	-	2,385.2	15.3	(17,148.0)	-	(17,148.0)	19,763.9	5,016.4
Whitman	-	(387.2)	(9,744.4)	3.7	14.7	18.4	104.1	(10,009.1)
Northwest	**127,713.0**	**43,144.3**	**12,094.5**	**(479.5)**	**(9,936.8)**	**29,222.8**	**(45,896.9)**	**38,564.6**
Island	-	709.3	(126.1)	-	-	-	(10.8)	572.4
King	65,543.0	13,424.0	2,200.2	3.5	49,654.2	42,924.7	(63,202.0)	(4,653.1)
Kitsap	(2,274.0)	3,987.6	(229.6)	(100.0)	-	(2,374.0)	-	1,384.0
San Juan	-	4.6	(52.5)	-	-	-	4.0	(43.9)
Skagit	(5,981.0)	26.2	72.9	-	-	(5,981.0)	(123.6)	(6,005.5)
Snohomish	70,114.0	25,224.6	7,956.1	-	(60,262.0)	(5,946.0)	15,330.5	42,565.3
Whatcom	311.0	(232.0)	2,273.5	(383.0)	671.0	599.0	2,105.0	4,745.5
Southwest	**3,738.4**	**63,566.9**	**(17,409.1)**	**641.4**	**1,070.0**	**5,449.9**	**(315.3)**	**69,319.2**
Clallam	-	1,236.5	-	-	-	-	(1,453.5)	(217.0)
Clark	-	99.0	-	-	-	-	-	99.0
Cowlitz	-	18,026.9	-	-	-	-	-	18,026.9
Grays	-	-	-	-	(3.8)	(3.8)	230.1	226.3
Jefferson	-	2,911.7	25.0	-	-	-	(61.7)	2,875.0
Lewis	-	11.2	-	-	-	-	-	11.2
Mason	-	2,803.0	-	1,783.0	93.0	1,876.0	135.2	4,814.3
Pierce	-	58,274.6	(17,405.0)	(1,055.0)	836.9	(218.2)	645.4	41,296.9
Thurston	3,738.4	(1,769.0)	(29.1)	(86.6)	144.0	3,795.8	189.1	2,186.7
Total	107,053.6	139,849.5	(4,195.0)	7,070.2	(8,900.4)	15,397.4	(39,816.3)	111,235.5

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b), Facilities processing biosolids associated with wastewater treatment plants are not included in the table. Total food waste includes food processing waste (pre-consumer), food waste (post-consumer), food waste all other (incl. pre-consumer), and mixed yard debris / food waste.

Net flows of organic material processed by industrial composting facilities required to report to Ecology under WAC 173-350-220, transported within and between Washington State counties in 2018, by county:

Source county or region	Destination county	Feedstock provisioned (tons)
Adams	Adams	472.7
Benton	Adams	137.3
	Benton	11,350.0
	Yakima	2,306.0
Chelan	Chelan	11,173.6
	Grant	1.5
	Yakima	1,554.3
Clallam	Clallam	3,121.2
	Jefferson	235.0
	Mason	499.0
Clark	Clark	624.0
	Cowlitz	6,957.0
	Klickitat	5,555.0
Columbia	Columbia	91.2
Douglas	Grant	42.6
Franklin	Adams	1,600.9
	Franklin	23.0
	Yakima	429.1
Garfield	Columbia	95.3
Grant	Adams	4,891.1
	Chelan	1,356.7
	Grant	43,921.6
Grays Harbor	Grays Harbor	364.1
ID	Lincoln	3,480.8
Island	Island	2,705.6
Jefferson	Jefferson	4,540.0
King	King	238,631.9
	Kitsap	7,764.8
	Pierce	7.5
	Snohomish	126,346.6
Kitsap	Mason	9,924.0
Kittitas	Kittitas	2,657.9
	Yakima	1,291.0
Klickitat	Klickitat	1,012.0
Lewis	Lewis	16.6
	Thurston	1,962.5
Lincoln	Grant	75.3

Source county or region	Destination county	Feedstock provisioned (tons)
	Lincoln	475.0
Mason	Mason	473.3
	Thurston	68.0
Okanogan	Mason	738.0
OR	Cowlitz	11,070.0
	Klickitat	29,068.0
	Pierce	80.0
Pend Oreille	Lincoln	71.8
Pierce	Clallam	606.0
	Klickitat	3,307.0
	Mason	150.0
	Pierce	202,237.5
	Thurston	37,287.5
San Juan	San Juan	395.1
Skagit	Mason	36.0
	Skagit	7,995.7
Skamania	Klickitat	5.0
Snohomish	Adams	184.0
	Snohomish	200,074.3
Spokane	Lincoln	80,207.2
	Spokane	2,885.0
Thurston	King	3,106.4
	Mason	417.0
	Thurston	22,584.3
Walla Walla	Walla Walla	61,020.0
Whatcom	Whatcom	30,709.4
Whitman	Lincoln	16.2
	Whitman	1,579.6
Yakima	Yakima	72,711.3

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the table.

Feedstock provisioned to industrial composting facilities that operated in Washington State during 2018, required to report to Ecology under WAC 173-350-220, by source county, destination county, and facility:

Source county or region	Destination county	Compost facility	Feedstock provisioned (tons)
Adams	Adams	Royal Organic Products	472.7
Benton	Adams	City of Richland Horn Rapids Composting	137.3
	Benton	Natural Selection Farms Composting Facility	11,350.0
	Yakima	Royal Organic Products	2,306.0
Chelan	Chelan	Natural Selection Farms Composting Facility	11,173.6
	Grant	Quincy Compost	1.5
	Yakima	Stemilt World Famous Compost Facility	1,554.3
Clallam	Clallam	City of Port Angeles Compost Facility	3,121.2
	Jefferson	North Mason Fiber Co.	235.0
	Mason	Shorts Family Farm	499.0
Clark	Clark	Cowlitz Valley Compost	624.0
	Cowlitz	Dirt Hugger LLC	6,957.0
	Klickitat	H & H Wood Recyclers	5,555.0
Columbia	Columbia	Columbia Compost*	91.2
Douglas	Grant	Quincy Compost	42.6
Franklin	Adams	Coyote Ridge Correction Center	1,600.9
	Franklin	Mesa Compost Facility	3.0
		Natural Selection Farms Composting Facility	20.0
	Yakima	Royal Organic Products	429.1
Garfield	Columbia	Columbia Compost*	95.3
Grant	Adams	Lawrence Farms LLC Compost Facility	4,891.1
	Chelan	Ovenell Farms Composting Facility	1,356.7
	Grant	Royal Organic Products	6,540.0
		Stemilt World Famous Compost Facility	37,381.6
Grays Harbor	Grays Harbor	Stafford Creek Corrections Center	364.1
ID	Lincoln	Barr-Tech Composting Facility**	3,480.8
Island	Island	Mailliard's Landing Nursery	2,486.9
		Wildwood Farm LLC	218.7
Jefferson	Jefferson	City of Port Townsend Compost Facility	3,694.6
		Shorts Family Farm	845.4
King	King	Bailand Farms Yardwaste (Bailey) Compost	235,188.0
		Cedar Grove Composting Co. Maple Valley	144.7
		Cedar Grove Composting, Inc.	2,569.7
		Green Pet Compost Company, LLC	104.4
		Lenz Enterprises Inc	625.0
	Kitsap	Olympic Organics LLC	7,764.8
	Pierce	Pacific Topsoils - Maltby	7.5

Source county or region	Destination county	Compost facility	Feedstock provisioned (tons)
	Snohomish	Seattle University Onsite Composting	5,000.0
	Snohomish	Steerco/Sawdust Supply	23,465.0
	Snohomish	UW Seattle Campus Compost Facility	67,872.0
	Snohomish	Woodland Park Zoo	30,009.6
Kitsap	Mason	North Mason Fiber Co.	9,924.0
Kittitas	Kittitas	Kittitas County Compost Facility	2,657.9
Kittitas	Yakima	Natural Selection Farms Composting Facility	1,291.0
Klickitat	Klickitat	Dirt Hugger LLC	1,012.0
Lewis	Lewis	Centralia Composting	16.6
Lewis	Thurston	Silver Springs Organics Composting LLC	1,962.5
Lincoln	Grant	Barr-Tech Composting Facility**	75.3
Lincoln	Lincoln	Quincy Compost	475.0
Mason	Mason	North Mason Fiber Co.	228.0
Mason	Mason	Silver Springs Organics Composting LLC	245.3
Mason	Thurston	WA Corrections Center Composting Facility	68.0
Okanogan	Mason	North Mason Fiber Co.	738.0
OR	Cowlitz	Cowlitz Valley Compost	11,070.0
OR	Klickitat	Dirt Hugger LLC	29,068.0
OR	Pierce	Green Pet Compost Company, LLC	80.0
Pend Oreille	Lincoln	Barr-Tech Composting Facility**	71.8
Pierce	Clallam	City of Port Angeles Compost Facility	606.0
Pierce	Klickitat	Dirt Hugger LLC	3,307.0
Pierce	Mason	Green Pet Compost Company, LLC	150.0
Pierce	Pierce	JBLM PCSS Storage + Treatment & Composting	72.1
Pierce	Pierce	LRI Compost Factory	2,490.0
Pierce	Pierce	North Mason Fiber Co.	151,367.0
Pierce	Pierce	Pierce County (Purdy) Composting Facility	48,052.0
Pierce	Pierce	Silver Springs Organics Composting LLC	256.4
Pierce	Thurston	WA Corrections Center for Women Compost	37,287.5
San Juan	San Juan	Midnight's Farm	395.1
Skagit	Mason	Dykstra Farm	36.0
Skagit	Skagit	North Mason Fiber Co.	904.7
Skagit	Skagit	Skagit Soils Inc	7,091.0
Skamania	Klickitat	Dirt Hugger LLC	5.0
Snohomish	Adams	Bailand Farms Yardwaste (Bailey) Compost	184.0
Snohomish	Snohomish	Cedar Grove Composting, Inc.	12,000.0
Snohomish	Snohomish	Lenz Enterprises Inc	123,187.0
Snohomish	Snohomish	Pacific Topsoils - Maltby	6,989.0
Snohomish	Snohomish	Riverside Topsoil Inc	32,554.1
Snohomish	Snohomish	Royal Organic Products	3,344.2

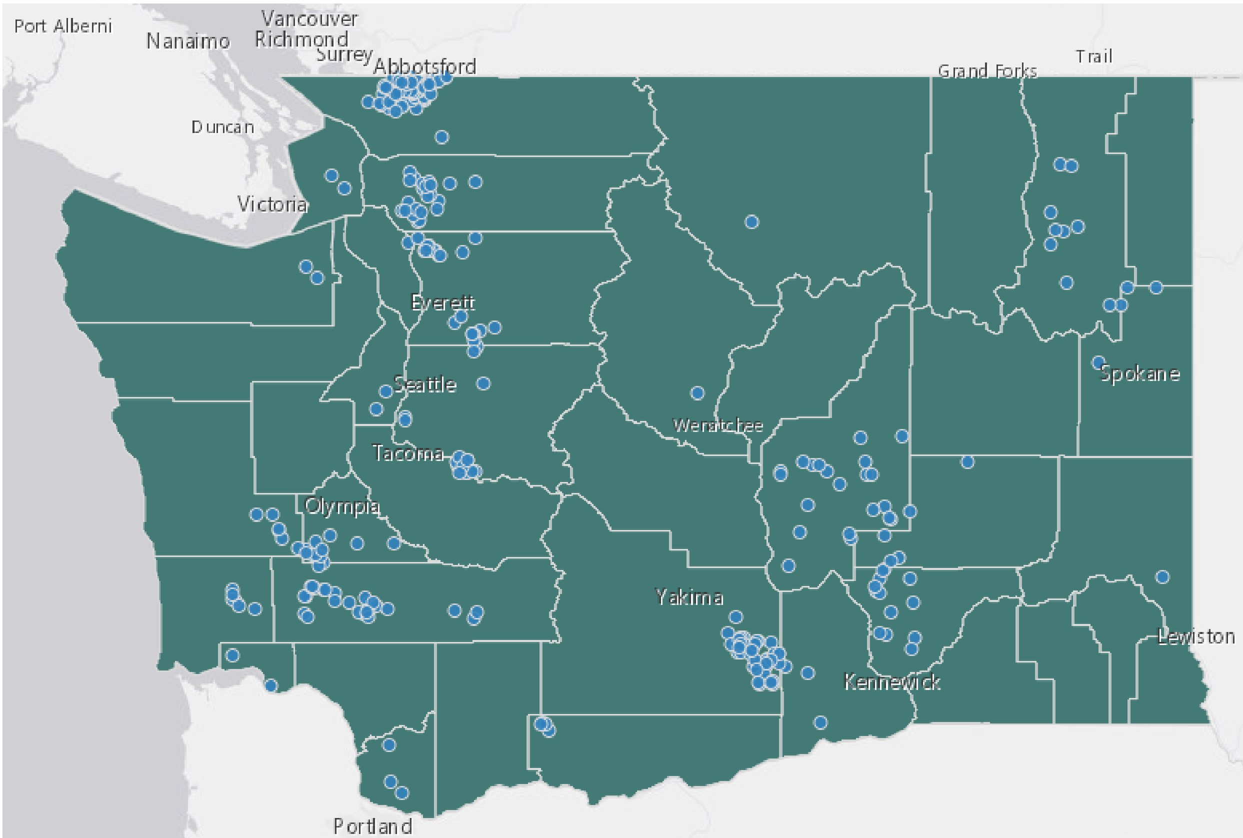
Source county or region	Destination county	Compost facility	Feedstock provisioned (tons)
		Thomas Farm Agricultural Composting	22,000.0
Spokane	Lincoln	Barr-Tech Composting Facility**	80,207.2
	Spokane	Cheney WWTP & Compost Facility*	2,885.0
Thurston	King	Cedar Creek Corrections Center*	3,106.4
	Mason	North Mason Fiber Co.	417.0
	Thurston	Silver Springs Organics Composting LLC	223.3
		Steerco/Sawdust Supply	22,361.0
Walla Walla	Walla Walla	Boise White Paper LLC	54,626.5
		Sudbury Landfill Compost Facility	6,393.5
Whatcom	Whatcom	Green Earth Technology (Compost)	27,356.0
		Smit's Compost	3,353.4
Whitman	Lincoln	Barr-Tech Composting Facility**	16.2
	Whitman	WSU Compost Facility	1,579.6
Yakima	Yakima	Apple tree resort	106.8
		Colonial Lawn & Garden Inc	312.0
		Natural Selection Farms Composting Facility	41,392.5
		Sunnyside Dairy	30,900.0

Table shows composting facilities reporting to Ecology for the year 2018. Data adopted from Ecology (2019b). Facilities processing biosolids associated with wastewater treatment plants are not included in the table.

Volume of compost (in tons) produced at industrial composting facilities that operated in Washington State during 2018, required to report to Ecology under WAC 173-350-220, by region and county:

County	Compost produced (tons)
Central	**87,104**
Benton	2,201
Chelan	16,051
Kittitas	1,379
Klickitat	15,155
Yakima	52,318
Eastern	**88,063**
Adams	10,462
Columbia	0
Franklin	21
Grant	21,377
Lincoln	37,868
Spokane	2,780
Walla Walla	10,278
Whitman	5,277
Northwest	**375,953**
Island	5,946
King	106,053
Kitsap	5,673
San Juan	385
Skagit	11,732
Snohomish	232,772
Whatcom	13,393
Southwest	**142,114**
Clallam	2,565
Clark	624
Cowlitz	37,675
Grays Harbor	7
Jefferson	3,361
Lewis	44
Mason	13,845
Pierce	60,711
Thurston	23,283
Total	693,234

Appendix 5: Dairy Operations in Washington (2018)



Source: Based on Washington Geospatial Open Data Portal. (2020, August 26). WA Dairies. See https://geo.wa.gov/datasets/26add7da921d4aa68ccb50ce191c6182_0?geometry=-128.600%2C45.437%2C-113.780%2C48.071

Appendix 6: Land application sites permitted in Washington (2017)

Land application sites that operated in Washington State during 2018, required to report to Ecology under WAC 173-350-230:

Facility Name	County	Region
ChemRad, Inc.	Benton	Central
Columbia Crest Winery	Benton	Central
ConAgra Lamb Weston Inc. Land Application Facility	Franklin	Eastern
Coventry Vale Winery	Benton	Central
Dungeness Development Association-Swogger Farm & Rose Ranch	Pacific	Southwest
Hogue Ranches, LLC	Benton	Central
Jessie's Ilwaco Fish Company	Pacific	Southwest
JR Simplot Company	Adams	Eastern
JR Simplot Moses Lake	Grant	Eastern
M and J Farms	Cowlitz	Southwest
McCain Foods USA Inc	Adams	Eastern
Skookum Farms	Grays Harbor	Southwest
Warden Industrial Wastewater Treatment	Grant	Eastern
Western Polymer	Grant	Eastern
WSP Correctional Industries Land Application	Walla Walla	Eastern

Appendix 7: Facilities in Washington that operated hog fuel boilers (2003)

The table below includes 31 facilities that are operative as of 2021 and that reported to be operating a hog fuel boilers since 2003. The specific status of each of these facilities should be known to local clean air agencies throughout the state.

Brooks Manufacturing	Pacific Hardwoods
Buffelen Woodworking	Pacific Veneer
Cascade Hardwood	Ponderay Newsprint, Co.
Clearwater Paper Corp	Roseburg Forest Products
Fred Tebb & Sons	Shakertown 1992
Georgia Pacific Camas	Simpson Timber NW Operations
Hardel Plywood	Stimson Lumber Company
High Cascade Forest LLC	Wayne-Dalton Corporation
Hoquiam Plywood	Western Forest Products
Kapstone Kraft Paper	Western State Hospital
Koenig FA & Sons	Weyerhaeuser Statewide
Laymans Lumber	Weyerhaeuser Cosmopolis
Longview Fibre	Weyerhaeuser Longview
Morton Forest Products	Wilkins, Kaiser, & Olsen
Mt. Baker Plywood	Zosel Lumber
NW Hardwoods	

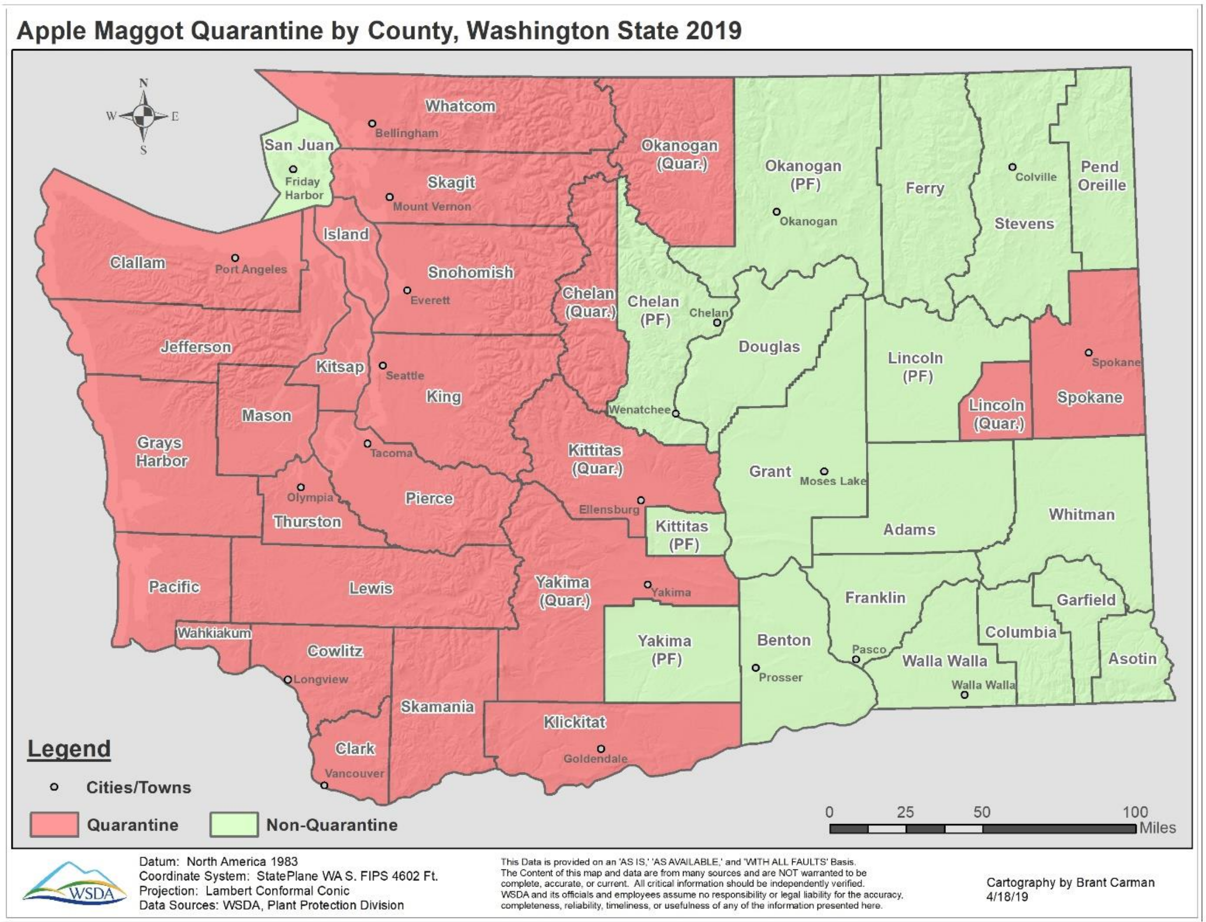
Source: Based on Ecology (2003) and Herrera (2018)

Appendix 8. Landfills in Washington receiving organics (2017)

Landfills receiving solid waste streams containing organics that operated in Washington during 2017:

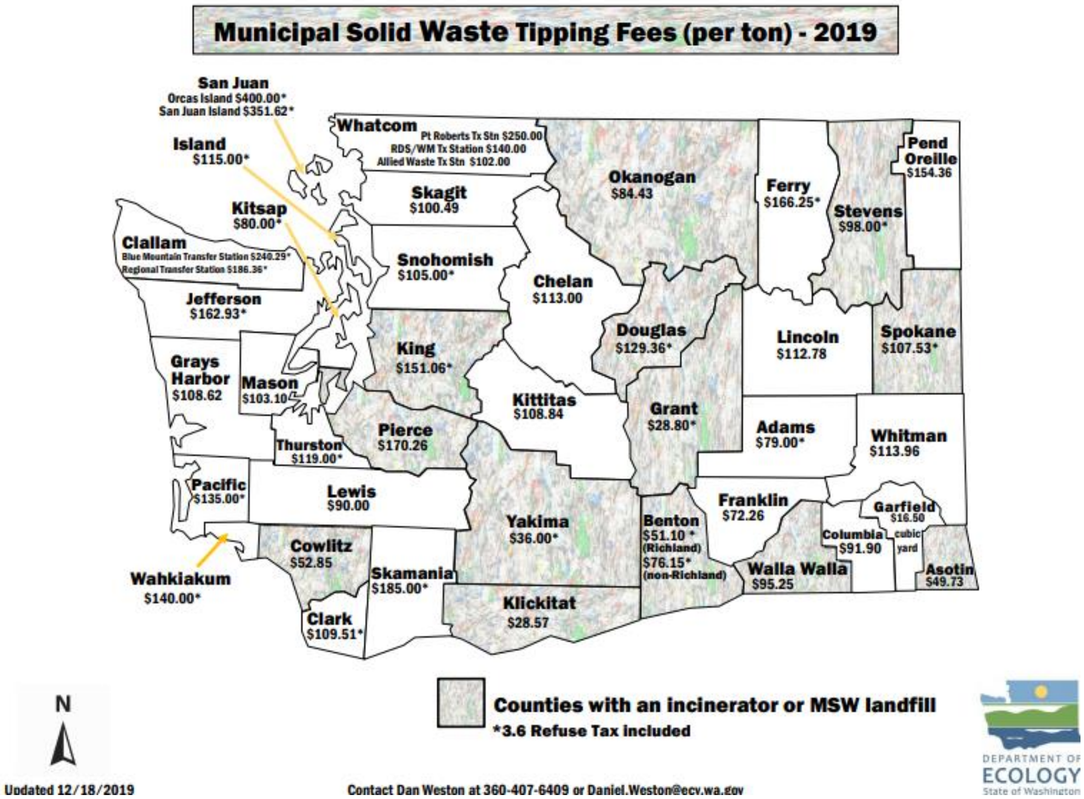
Facility Name	Organic Feedstock 2017 (tons)	County	Region
Asotin County Regional Landfill	56,000	Asotin	Eastern
Cedar Hills Regional Landfill	928,626	King	Northwest
Cheyne Road Landfill	84,636	Yakima	Central
Cowlitz County Headquarters Landfill	179,393	Cowlitz	Southwest
Ephrata Landfill	114,863	Grant	Eastern
Greater Wenatchee Regional Landfill	240,449	Douglas	Central
Horn Rapids Sanitary Landfill	48,410	Benton	Central
LRI Landfill	663,886	Pierce	Southwest
Northside Landfill	4,434	Spokane	Eastern
Okanogan Central Landfill	34,777	Okanogan	Central
Roosevelt Regional Landfill MSW	1,406,958	Klickitat	Central
Stevens County Landfill	24,071	Stevens	Eastern
Sudbury Regional Landfill	50,096	Walla Walla	Eastern
Terrace Heights Landfill	190,170	Yakima	Central

Appendix 9. Apple maggot quarantined areas in Washington (2019)



Source: WSDA (n.d.)

Appendix 10. Municipal solid waste tipping fees per ton (2019)



Source: Ecology (2019c)